M3T-MR32R V.3.50

Real-time OS for M32R Family

User's Manual

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Preface

The M3T-MR32R(abbreviated as MR32R) is a real-time operating system[1] 1for the M32R microcomputers. The MR32R conforms to the μITRON Specification.[2]
This manual describes the procedures and precautions to observe when you use the MR32R for programming purposes. For the detailed information on individual system call procedures, refer to the MR32R Reference Manual.

Requirements for MR32R Use

When creating programs based on the MR32R, it is necessary to purchase the following product of Mitsubishi Electric or third party products.

- M32R Family Compiler DCC/M32R(Windriver systems, Inc)
- M32R Family Cross tool M3T-CC32R(abbreviated as CC32R)
- M32R Family GNU Cross tool M3T-TW32R(abbreviated as TW32R)
  When these related products are used, increased program development efficiency is obtained.

Document List

The following sets of documents are supplied with the MR32R.

- Release Note
  Presents a software overview and describes the corrections to the Users Manual and Reference Manual.
- Users Manual (PDF file)
  Describes the procedures and precautions to observe when using the MR32R for programming purposes.
- Reference Manual (PDF file)
  Describes the MR32R system call procedures and typical usage examples. Before reading the Users Manual, be sure to read the Release Note.
  Please read the release note before reading this manual.

Right of Software Use

The right of software use conforms to the software license agreement. You can use the MR32R for your product development purposes only, and are not allowed to use it for the other purposes. You should also note that this manual does not guarantee or permit the exercise of the right of software use.

[1] Hereinafter abbreviated "real-time OS"
[2] The μITRON Specification is originated by Dr.Ken Sakamura and his laboratory members at the Faculty Science of University of Tokyo. Therefore,Dr.Ken Sakamura holds the copyright on the μITRON Specification. By his consent,the MR32R is produced in compilance with the μITRON Specification.

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Chapter 1 User's Manual Organization

The MR32R User's Manual consists of nine chapters and thee appendix.

- Chapter 1 User's Manual Organization
  Outlines the contents of MR32R User's Manual.

- Chapter 2 General Information
  Outlines the objective of MR32R development and the function and position of the MR32R.

- Chapter 3 Introduction to MR32R
  Explains about the ideas involved in MR32R operations and defines some relevant terms.

- Chapter 4 Applications Development Procedure Overview
  Outlines the applications program development procedure for the MR32R.

- Chapter 5 Detailed Applications
  Details the applications program development procedure for the MR32R.

- Chapter 7 Using Configurator
  Describes the method for writing a configuration file and the method for using the configurator in detail.

- Chapter 8 How to Customize
  This chapter explains how to customize the startup file, the interrupt control program section file, and makefile so as to make them conform to a user's system.

- Chapter 9 Application Creation Guide
  Presents useful information and precautions concerning applications program development with MR32R.

- Chapter 10 Apendex
  Describes the MR32R sample applications program which is included in the product in the form of a source file.

Chapter 2 General Information

2.1 Objective of MR32R Development

In line with recent rapid technological advances in microcomputers, the functions of microcomputer-based products have become complicated. In addition, the microcomputer program size has increased. Further, as product development competition has been intensified, manufacturers are compelled to develop their microcomputer-based products within a short period of time.
In other words, engineers engaged in microcomputer software development are now required to develop larger-size programs within a shorter period of time. To meet such stringent requirements, it is necessary to take the following considerations into account.

1. **To enhance software recyclability to decrease the volume of software to be developed.**

   One way to provide for software recyclability is to divide software into a number of functional modules wherever possible. This may be accomplished by accumulating a number of general-purpose subroutines and other program segments and using them for program development. In this method, however, it is difficult to reuse programs that are dependent on time or timing. In reality, the greater part of application programs are dependent on time or timing. Therefore, the above recycling method is applicable to only a limited number of programs.

2. **To promote team programming so that a number of engineers are engaged in the development of one software package**

   There are various problems with team programming. One major problem is that debugging can be initiated only when all the software program segments created individually by team members are ready for debugging. It is essential that communication be properly maintained among the team members.

3. **To enhance software production efficiency so as to increase the volume of possible software development per engineer.**

   One way to achieve this target would be to educate engineers to raise their level of skill. Another way would be to make use of a structured descriptive assembler, C-compiler, or the like with a view toward facilitating programming. It is also possible to enhance debugging efficiency by promoting modular software development.

However, the conventional methods are not adequate for the purpose of solving the problems. Under these circumstances, it is necessary to introduce a new system named real-time OS
To answer the above-mentioned demand, Mitsubishi Electric has developed a real-time operating system, tradenamed MR32R, for use with the M32R 32-bit one-chip microcomputers.
When the MR32R is introduced, the following advantages are offered.

1. **Software recycling is facilitated.**

   When the real-time OS is introduced, timing signals are furnished via the real-time OS so that programs dependent on timing can be reused. Further, as programs are divided into modules called tasks, structured programming will be spontaneously provided.
   That is, recyclable programs are automatically prepared.

2. **Ease of team programming is provided.**

   When the real-time OS is put to use, programs are divided into functional modules called tasks. Therefore, engineers can be allocated to individual tasks so that all steps from development to debugging can be conducted independently for each task.
   Further, the introduction of the real-time OS makes it easy to start debugging some already finished tasks even if the entire program is not completed yet. Since engineers can be allocated to individual tasks, work assignment is easy.

3. **Software independence is enhanced to provide ease of program debugging.**

   As the use of the real-time OS makes it possible to divide programs into small independent modules called tasks, the greater part of program debugging can be initiated simply by observing the small modules.

4. Timer control is made easier.

To perform processing at 10 msec intervals, the microcomputer timer function was formerly used to periodically initiate an interrupt. However, as the number of usable microcomputer timers was limited, timer insufficiency was compensated for by, for instance, using one timer for a number of different processing operations.
When the real-time OS is introduced, however, it is possible to create programs for performing processing at fixed time intervals making use of the real-time OS time management function without paying special attention to the microcomputer timer function. At the same time, programming can also be done in such a manner as to let the programmer take that numerous timers are provided for the microcomputer.

5. Software maintainability is enhanced.

When the real-time OS is put to use, the developed software consists of small program modules called tasks. Therefore, increased software maintainability is provided because developed software maintenance can be carried out simply by maintaining small tasks.

6. Increased software reliability is assured.

The introduction of the real-time OS makes it possible to carry out program evaluation and testing in the unit of a small module called task. This feature facilitates evaluation and testing and increases software reliability.

7. The microcomputer performance can be optimized to improve the performance of microcomputer-based products.

With the real-time OS, it is possible to decrease the number of unnecessary microcomputer operations such as I/O waiting. It means that the optimum capabilities can be obtained from microcomputers, and this will lead to microcomputer-based product performance improvement.

2.2 Relationship between TRON Specification and MR32R

The TRON Specification is an abbreviation for The Real-time Operating system Nucleus specification. It denotes the specifications for the nucleus of a real-time operating system. The TRON Project, which is centered on TRON Specification design, is pushed forward under the leadership of Dr. Ken Sakamura at Faculty of Science, University of Tokyo.
As one item of this TRON Project, the ITRON Specification is promoted. The ITRON Specification is an abbreviation for the Industrial TRON Specification. It denotes the real-time operating system that is designed with a view toward establishing industrial real-time operating systems.
The ITRON Specification provides a number of functions to properly meet the application requirements. In other words, ITRON systems require relatively large memory capacities and enhanced processing capabilities. The μITRON Specification V.2.0 is the arranged version of the ITRON Specification for the higher processing speed, and incorporated only a minimum of functions necessary. The μITRON Specification V.2.0 can be said to be a subset of the ITRON Specification for the following reasons.

1. **The system call time-out function is not incorporated.**

2. **Tasks, semaphores, and other objects can be generated only at the time of system generation.[3] They cannot be generated after system startup.[4]**

3. **Only memorypools of a fixed-size can be handled. Memorypools of a variable-size cannot be handled.**

4. **Neither the system call exception management function nor the CPU exception management function is provided.**

Currently stipulated are μITRON specifications V.3.0. The μITRON specifications V.3.0 provides enhanced connection functions by integrating μITRON specifications V.2.0 and ITRON specifications.
MR32R is a real-time operating system developed for the M32R of 32-bit microprocessors according to the μITRON specification.4[5]
The μITRON specifications V.3.0 has its system calls classified into level R, level S,level E, and level C.
MR32R implements all of level R and level S system calls and part of level E system calls among those stipulated under μITRON specifications V.3.0.
The MR2R specifications are outlined inTable 2.1.

[3] Static object generation.
[4] Dynamic object generation
[5] MR32R V.3.40 conforms to μITRON Specifications V.3.0.

Table 2.1MR32R Specifications Overview

Item	Specifications
Target microprocessor	M32R Family
Maximum number of tasks	32767
Task priorities	255
Maximum number of eventflags	32766
Eventflag width	32 bits
Maximum number of semaphores	32766
Semaphore type	Counter type
Maximum number of mailboxes	32766
Message size	32 bits
Buffer size of Mailbox	more tha 4bytes
Maximum number of Messagebuffer	32765
Maximum number of port for rendezvous	32765
Maximum number of Fixed-size Memorypool	32766
Maximum number of Variable-size Memorypool	32766
Number of system calls	115
OS nucleus code size OS nucleus data size	Approx. 4 K to 50 K bytes 81 bytes min.,44 byte increment per task
OS nucleus language	C and Assembly language

* The sum of the number of eventflags, the highest priority, the number of semaphores, the number of mailbox with priority, (the number of the maximum milbox with priority – the number of mailbox with priority defined in the configuration file + the number of mailbox with priority defined in the configuration file and specified as TA_TPRI X the highest priority value of tasks), and number of mailboxes is not to exceed 32766.

2.3 MR32R Features

The MR32R offers the following features.

5. Real-time operating system conforming to the μITORN Specification.

The MR32R is designed in compliance with the μITRON Specification which incorporates a minimum of the ITRON Specification functions so that such functions can be incorporated into a one-chip microcomputer. As the μ ITRON Specification is a subset of the ITRON Specification, most of the knowledge obtained from published ITRON textbooks and ITRON seminars can be used as is.
Further, the application programs developed using the real-time operating systems conforming to the ITRON Specification can be transferred to the MR32R with comparative ease.

6. High-speed processing is achieved.

MR32R enables high-speed processing by taking full advantage of the microcomputer architecture.

7. Only necessary modules are automatically selected to constantly build up a system of the minimum size.

The MR32R is supplied in the form of a M32R family microcomputer objective library.
Therefore, the Linkage Editor functions are activated so that only necessary modules are automatically selected from numerous MR32R functional modules to generate a system.
Thanks to this feature, a system of the minimum size is automatically generated at all times.

8. With the C-compiler NC308, it is possible to develop application programs in C language.

When the C-compiler cc32R or TW32R is used, MR32R application programs can be developed in C language.Also note that an interface library is supplied on software disk to permit calling up the MR32R functions in C language.

9. An upstream process tool named "Configurator" is provided to simplify development procedures

A configurator is furnished so that various items including a ROM write form file can be created by giving simple definitions.
Therefore, there is no particular need to care what libraries must be linked.

Chapter 3 Introduction to MR32R

3.1 Concept of Real-time OS

This section explains the basic concept of real-time OS.

3.1.1 Why Real-time OS is Necessary

In line with the recent advances in semiconductor technologies, the single-chip microcomputer ROM capacity has increased. ROM capacity of 32K bytes.
As such large ROM capacity microcomputers are introduced, their program development is not easily carried out by conventional methods. Figure 3.1 shows the relationship between the program size and required development time (program development difficulty).
This figure is nothing more than a schematic diagram. However, it indicates that the development period increases exponentially with an increase in program size.
For example, the development of four 8K byte programs is easier than the development of one 32K byte program.[6]

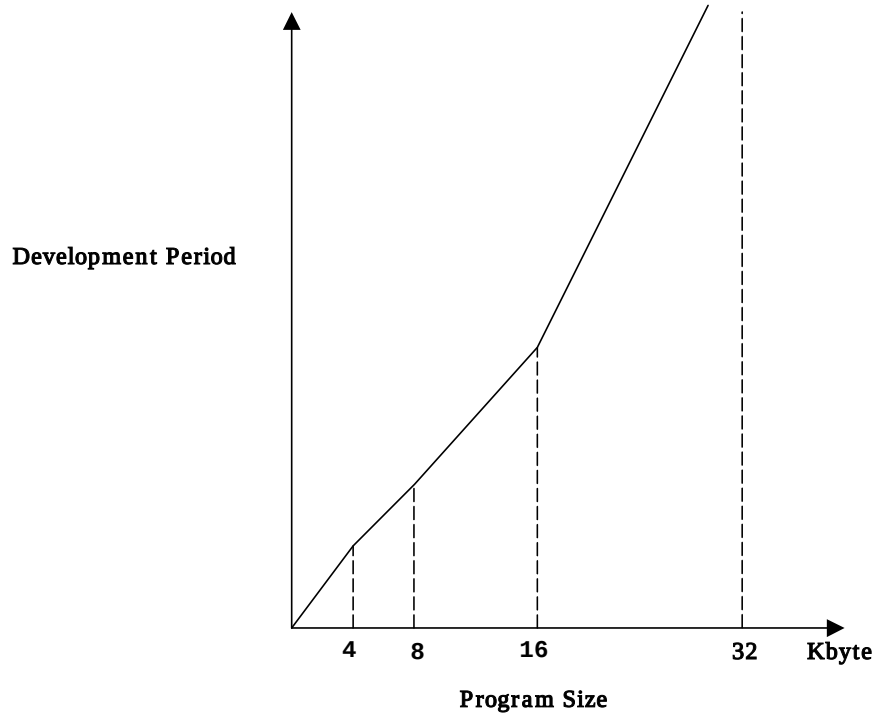


Figure 3.1 Relationship between Program Size and Development Period

Under these circumstances, it is necessary to adopt a method by which large-size programs can be developed within a short period of time. One way to achieve this purpose is to use a large number of microcomputers having a small ROM capacity. Figure 3.2 presents an example in which a number of microcomputers are used to build up an audio equipment system.

[6] On condition that the ROM program burning step need not be performed.

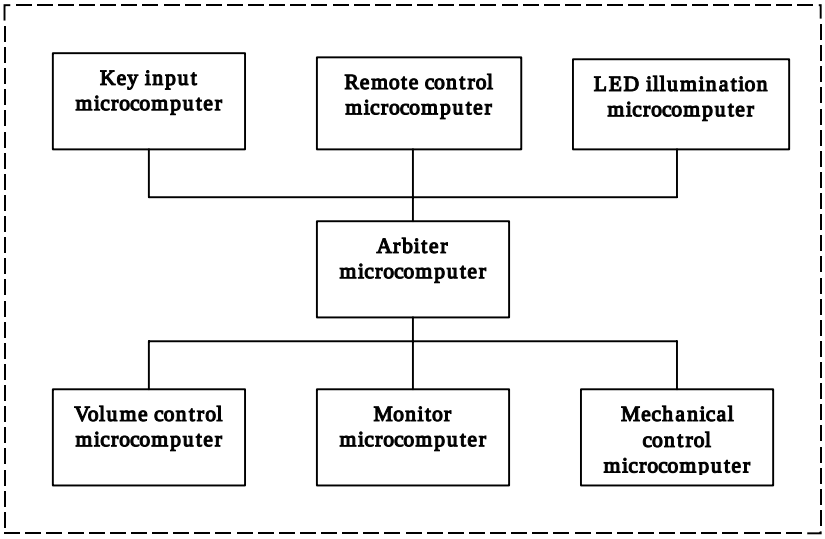


Figure 3.2 Microcomputer-based System Example(Audio Equipment)

Using independent microcomputers for various functions as indicated in the above example offers the following advantages.

1. **Individual programs are small so that program development is easy.**
2. **It is very easy to use previously developed software.**[7]
3. **Completely independent programs are provided for various functions so that program development can easily be conducted by a number of engineers.**

On the other hand, there are the following disadvantages.

1. **The number of parts used increases, thereby raising the product cost.**
2. **Hardware design is complicated.**
3. **Product physical size is enlarged.**

Therefore, if you employ the real-time OS in which a number of programs to be operatedby a number of microcomputers are placed under software control of one microcomputer, making it appear that the programs run on separate microcomputers, you can obviate all the above disadvantages while retaining the above-mentioned advantages.
Figure 3.3 shows an example system that will be obtained if the real-time OS is incorporated in the system indicated in Figure 3.2.

[7] In the case presented in Figure 3.2 for instance, the remote control microcomputer can be used for other products without being modified.

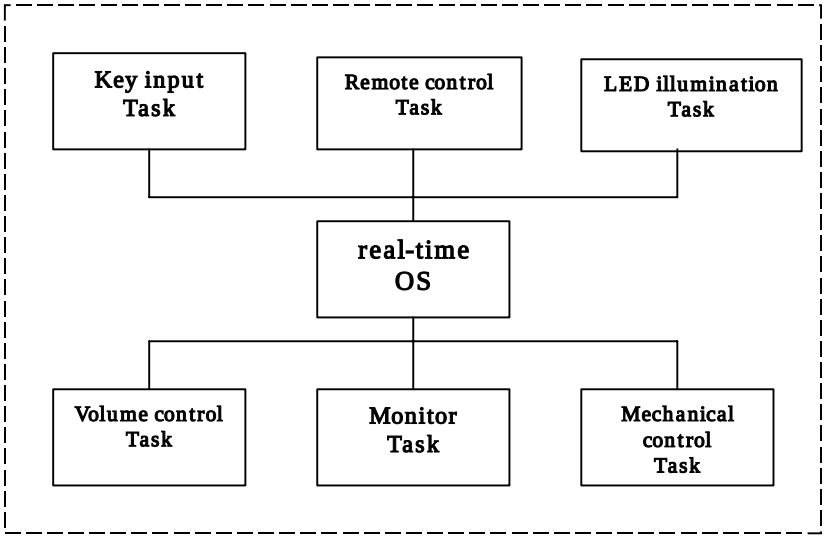


Figure 3.3 Example System Configuration with Real-time OS(Audio Equipment)

In other words, the real-time OS is the software that makes a one-microcomputer system look like operating a number of microcomputers.
In the real-time OS, the individual programs, which correspond to a number of microcomputers used in a conventional system, are called tasks.

3.1.2 Operating Principles of Real-time OS

The real-time OS is the software that makes a one-microcomputer system look like operating a number of microcomputers. You should be wondering how the real-time OS makes a one-microcomputer system function like a number of microcomputers.
As shown in Figure 3.4 the real-time OS runs a number of tasks according to the time-division system. That is, it changes the task to execute at fixed time intervals so that a number of tasks appear to be executed simultaneously.

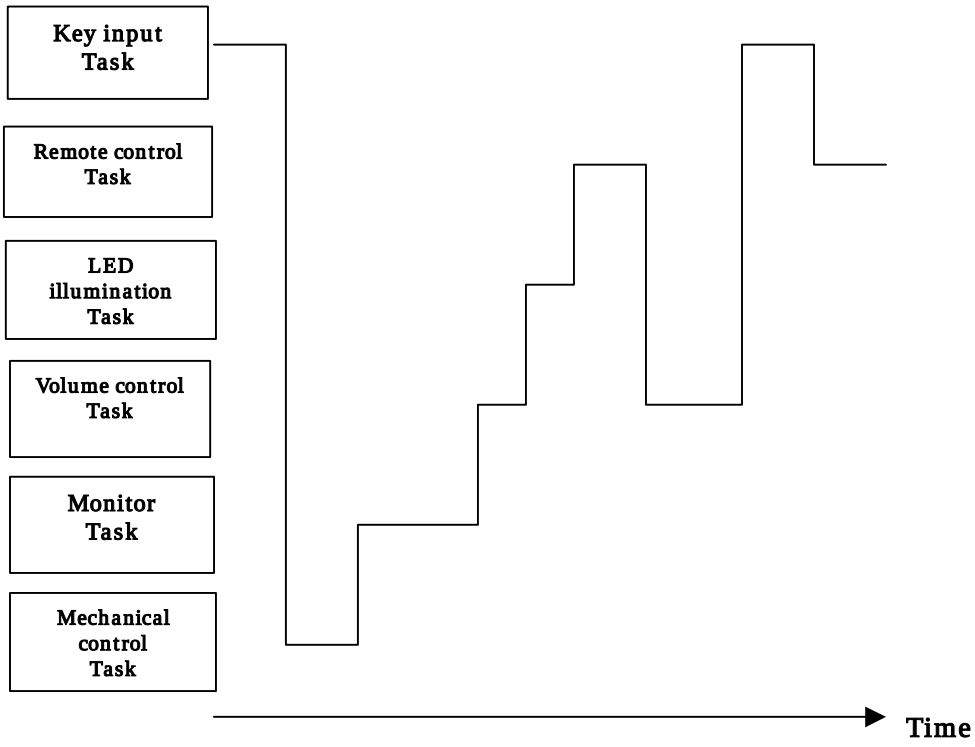


Figure 3.4 Time-division Task Operation

As indicated above, the real-time OS changes the task to execute at fixed time intervals. This task switching may also be referred to as dispatching (technical term specific to real-time operating systems). The factors causing task switching (dispatching) are as follows.

- Task switching occurs upon request from a task.
- Task switching occurs due to an external factor such as interrupt.

When a certain task is to be executed again upon task switching, the system resumes its execution at the point of last interruption (See Figure 3.5).

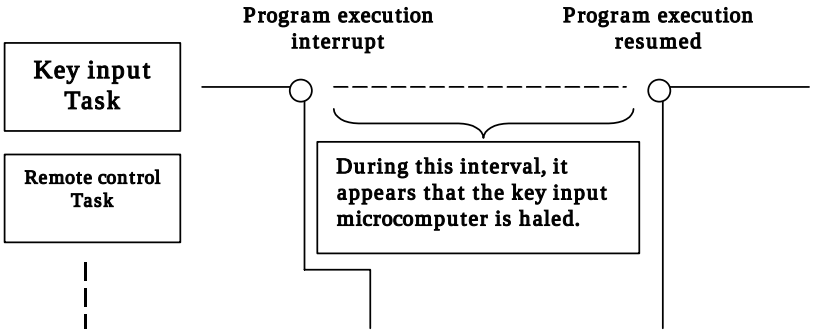

Program execution interrupt
Program execution resumed
Key input Task
Remote control Task
During this interval, it appears that the key input microcomputer is haled.

Figure 3.5 Task Execution Interruption and Resumption

In the state shown in Figure 3.5, it appears to the programmer that the key input task or its microcomputer is halted while another task assumes execution control.
Task execution restarts at the point of last interruption as the register contents prevailing at the time of the last interruption are recovered. In other words, task switching refers to the action performed to save the currently executed task register contents into the associated task management memory area and recover the register contents for the task to switch to.

To establish the real-time OS, therefore, it is only necessary to manage the register for each task and change the register contents upon each task switching so that it looks as if a number of micro-computers exist (See Figure 3.6).

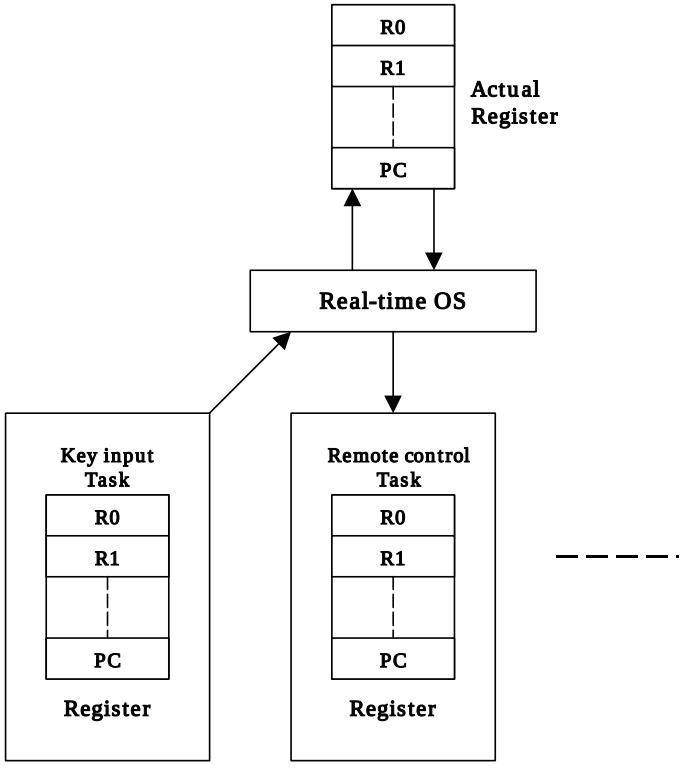


Figure 3.6 Task Switching

The example presented in Figure. 3.7 indicates how the individual task registers are managed. In real-

ity, it is necessary to provide not only a register but also a stack area for each task.

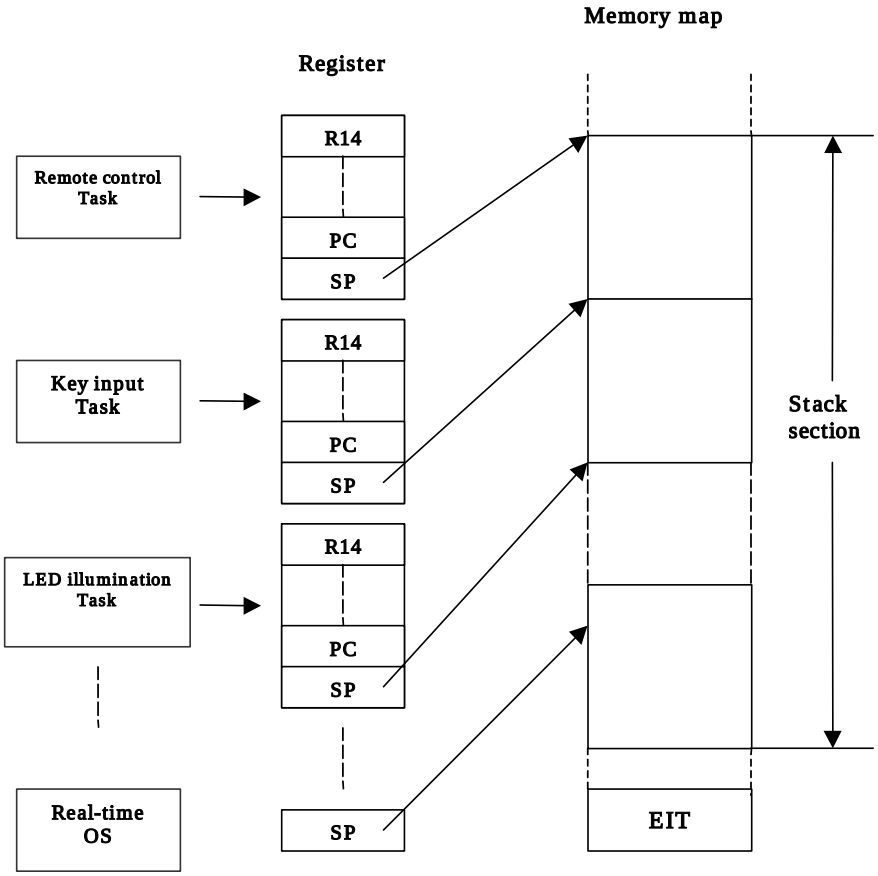


Figure 3.7 Task Register Area

Figure 3.8 shows the register and stack area of one task in detail. In the MR32R, the register of each task is stored in a stack area as shown in Figure 3.8. This figure shows the state prevailing after register storage.

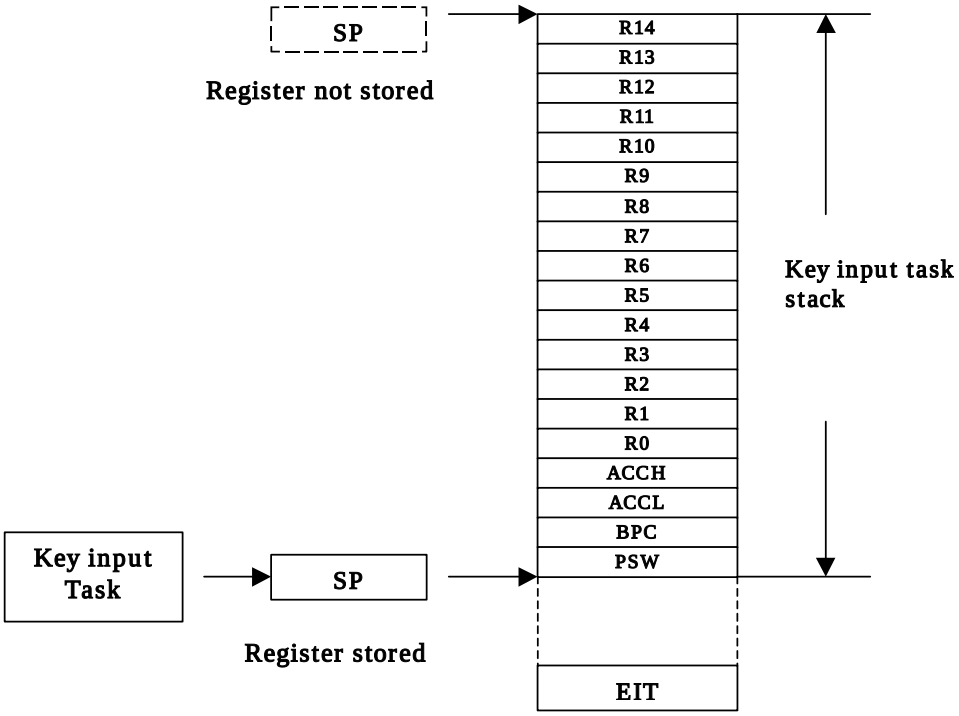


Figure 3.8 Actual Register and Stack Area Management

3.2 System Call

How does the programmer use the real-time OS in a program?
First, it is necessary to call up a real-time OS function from the program in some way or other. Calling a real-time OS function is referred to as a system call. Task activation and other processing operations can be initiated by such a system call (See Figure 3.9).

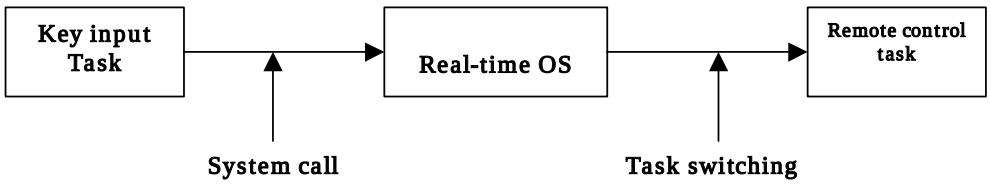


Figure 3.9 System Call

When application programs are to be written in C language, a system call is accomplished by making a function call, as indicated below.

```
sta_tsk(ID_main,3);
```

If application programs are to be written in assembly language, a system call is accomplished by making an assembler macro call, as indicated below.

```
sta_tsk ID_main,3
```

3.2.1 System Call Processing

When a system call is issued, processing takes place in the following sequence.[8]

1. **The current register contents are saved.**
2. **The stack pointer is changed from the task type to the real-time OS (system) type.**
3. **Processing is performed in compliance with the request made by the system call.**
4. **The task to be executed next is selected.**
5. **The stack pointer is changed to the task type.**
6. **The register contents are recovered to resume task execution.**

The flowchart in Figure 3.10 shows the process between system call generation and task switching.

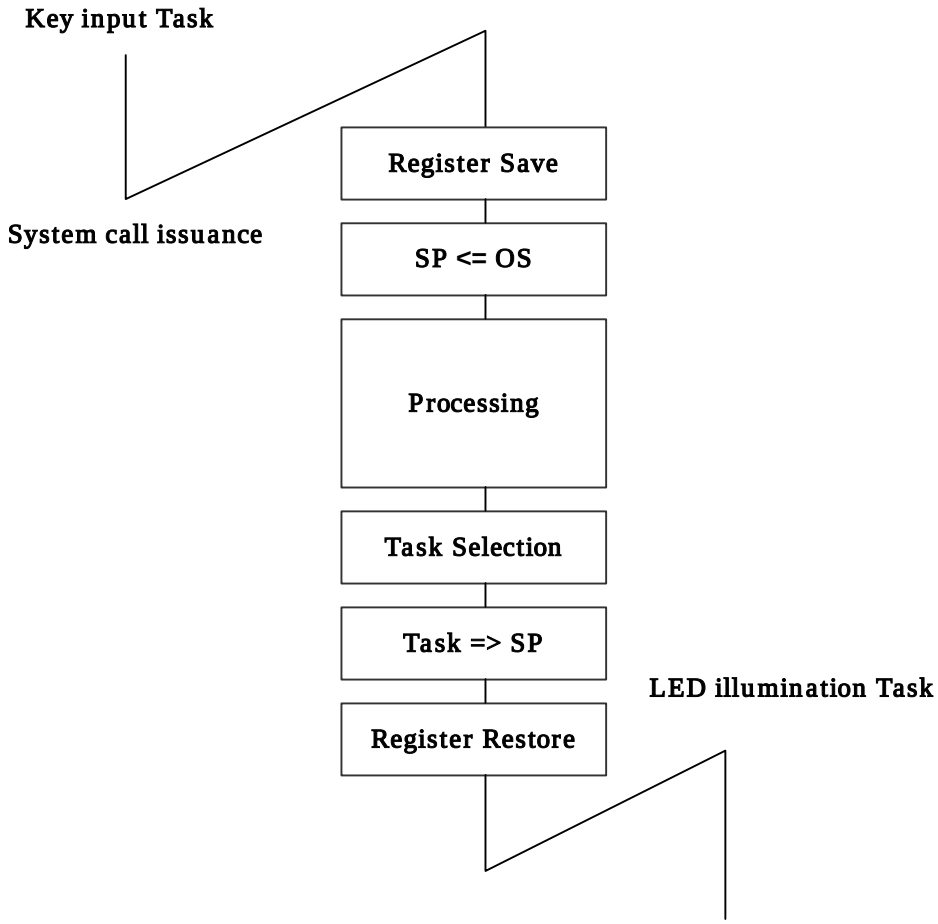


Figure 3.10 System Call Processing Flowchart

[8] A different sequence is followed if the issued system call does not evoke task switching.

3.2.2 Task Designation in System Call

Within the MR32R real-time OS, each task is identified by ID number.
For example, the system says, "Start the task having the task ID number 1."
However, if a task number is directly written in a program, the resultant program would be very low in readability. If, for instance, the following is entered in a program, the programmer is constantly required to know what the No. 2 task is.

```
sta_tsk(2,1);
```

Further, if this program is viewed by another person, he/she does not understand at a glance what the No. 2 task is. To avoid such inconvenience, the MR32R provides means of specifying the task by name (function or symbol name).

The program named "configurator cfg32r ,"which is supplied with the MR32R, then automatically converts the task name to the task ID number. This task identification system is schematized in Figure 3.11.

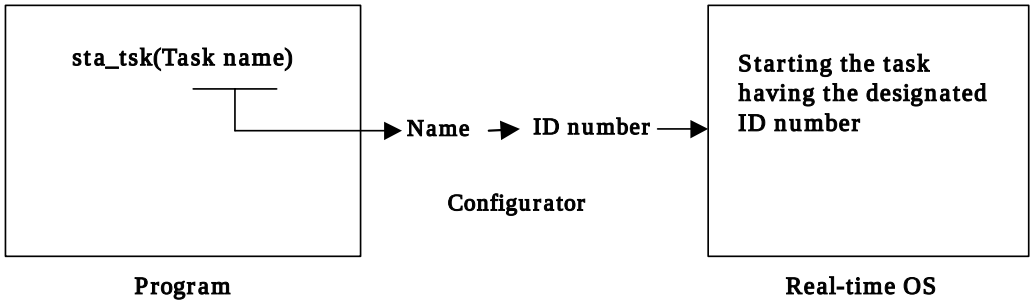


Figure 3.11 Task Identification

```
sta_tsk(ID_task,1);
```

In the above example, the system is instructed to start the task having the function name "task()" or the symbol name "task:".
It should also be noted that task name-to-ID number conversion is effected at the time of program generation. Therefore, the processing speed does not decrease due to this conversion feature.

3.3 Task

This chapter explains how the real-time OS controls the tasks.

3.3.1 Task Status

The real-time OS monitors the task status to determine whether or not to execute the tasks.
Figure 3.12 shows the relationship between key input task execution control and task status. When there is a key input, the key input task must be executed. That is, the key input task is placed in the execution (RUN) state. While the system waits for key input, task execution is not needed. In that situation, the key input task in the WAIT state.

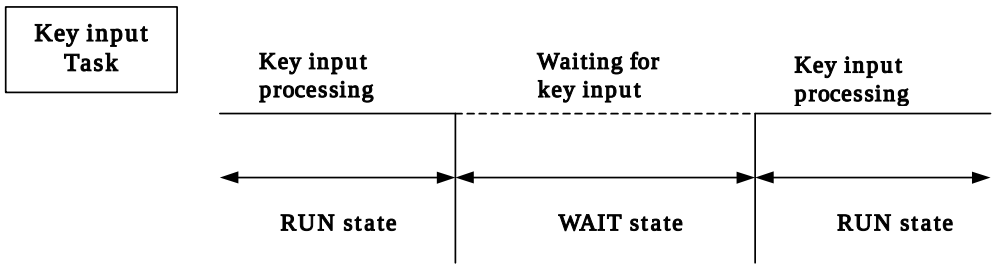


Figure 3.12 Task Status

The MR32R controls the following six different states including the RUN and WAIT states.

1. **RUN state**
2. **READY state**
3. **WAIT state**
4. **SUSPEND state**
5. **WAIT-SUSPEND state**
6. **DORMANT state**
7. **NON-EXISTENTstate**

Every task is in one of the above seven different states.Figure 3.13 shows task status transition.

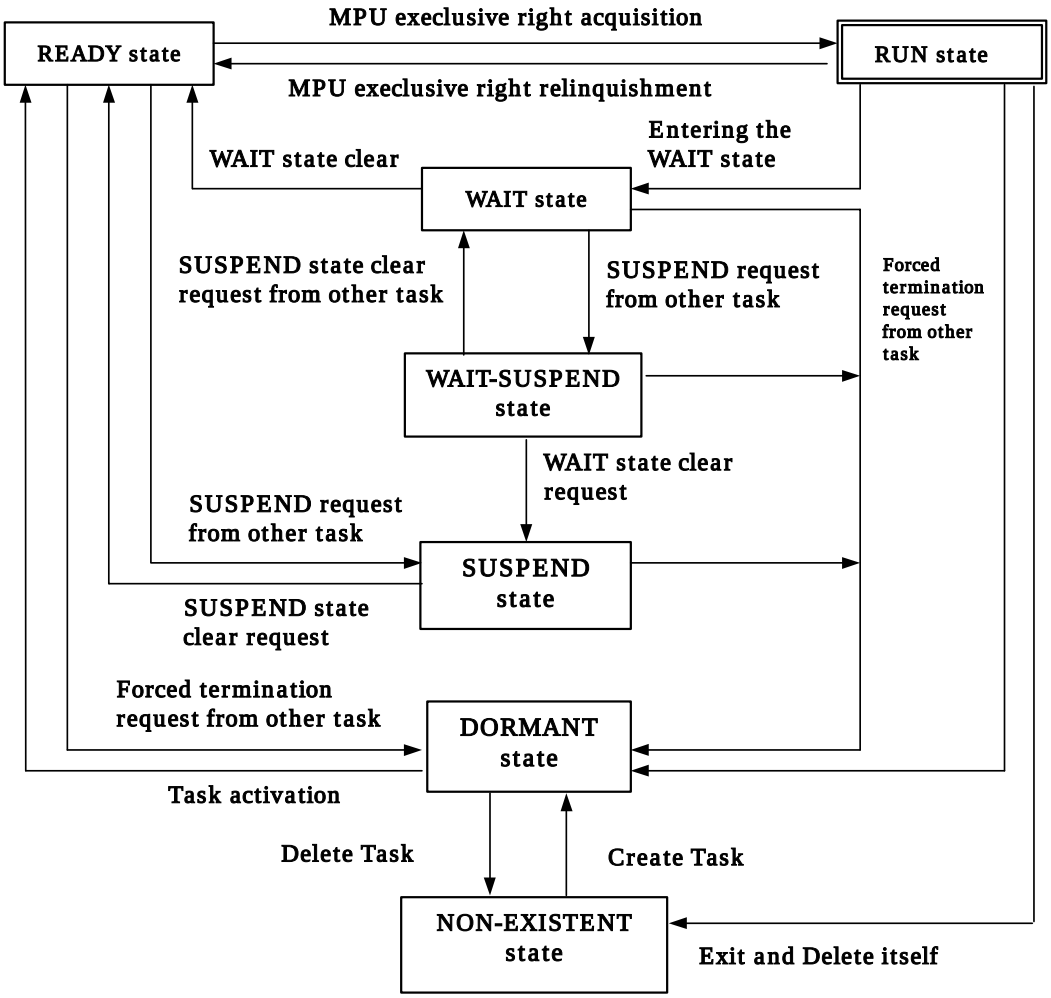


Figure 3.13 MR32R Task Status Transition

1. RUN state

In this state, the task is being executed. Since only one microcomputer is used, it is natural that only one task is being executed.
The currently executed task changes into a different state when any of the following conditions occurs.

- The task has normally terminated itself.[9]
- The task has placed itself in the WAIT state.[10]
- Due to interruption or other event occurrence, the interrupt handler has placed a different task having a higher priority in the READY state.
- The priority assigned to the task has been changed so that the priority of another READY task is rendered higher.[11]
- Due to interruption or other event occurrence, the priority of the task or a different READY task has been changed so that the priority of the different task is rendered

[9] Upon ext_tsk system call
[10] Upon slp_tsk, tslp_tsk, dly_tsk, wai_flg, twai_flg, wai_sem, twai_sem, rcv_msg or trcv_msg system call.
[11] Upon chg_pri system call.

higher.[12]

When any of the above conditions occurs, rescheduling takes place so that the task having the highest priority among those in the RUN or READY state is placed in the RUN state, and the execution of that task starts.

2. READY state

The READY state refers to the situation in which the task that meets the task execution conditions is still waiting for execution because a different task having a higher priority is currently being executed.

When any of the following conditions occurs, the READY task that can be executed second according to the ready queue[13] is placed in the RUN state.

- A currently executed task has normally terminated itself.
- A currently executed task has placed itself in the WAIT state.
- A currently executed task has changed its own priority so that the priority of a different READY task is rendered higher.[14]
- Due to interruption or other event occurrence, the priority of a currently executed task has been changed so that the priority of a different READY task is rendered higher.[15]

3. WAIT state

It exits the RUN state and enters the WAIT state. The WAIT state is usually used as the condition in which the completion of I/O device I/O operation or the processing of some other task is awaited.

The task goes into the WAIT state in one of the following ways.

- The task enters the WAIT state simply when the slp_tsk system call is issued.In this case, the task does not go into the READY state until its WAIT state is cleared explicitly by some other task.
- The task enters and remains in the WAIT state for a specified time period when the dly_tsk system call is issued. In this case, the task goes into the READY state when the specified time has elapsed or its WAIT state is cleared explicitly by some other task.
- When the wai_flg, wai_sem, rcv_msg, snd_mbf, rcv_mbf, cal_por, acp_por, get_blf, get_blk, vrcv_mbx system call is issued, the task enters the WAIT state and waits to be requested. In this case, the task moves into the READY state when the request condition is met or its WAIT state is cleared explicitly by some other task.
- tslp_tsk, wai_flg, twai_sem, trcv_msg, tsnd_mbf, trcv_mbf, tcal_por, tacp_por, tget_blf, tget_blk, vtrcv_mbx system call mean slp_tsk, wai_flg, wai_sem, rcv_msg, snd_mbf, rcv_mbf, cal_por, acp_por, get_blf, get_blk, vrcv_mbx system call with time-out specification. The task is moved to WAIT state by these system calls issue.In this case,the task is moved to READY state if their conditions are satisfied or the period specified by tmout elapses without conditions.

When the task enters the WAIT state and waits to be requested upon the issuance of the wai_flg,wai_sem,rcv_msg,snd_mbf,rcv_mbf,cal_por,acp_por,get_blf,get_blk system call.[16]

[12] Upon ichg_pri system call.
[13] For the information on the ready queue ,see the next chapter
[14] Upon chg_pri system call.
[15] Upon ichg_pri system call
[16] Upon slp_tsk,dly_tsk,wai_flg,wai_sem ,or rcv_msg system call.

- Eventflag Queue
- Semaphore Queue
- Mailbox Queue
- Send Messagebuffer Queue
- Receive Message Buffer Queue
- Call Wait Queu
- Accept Rendezvous Queue
- Fixed-size memory Allocation Queue
- Variable-size memory Allocation Queue
- Mailbox Queue with Priority

4. SUSPEND state

When the sus_tsk system call is issued from a task in the RUN state or the isus_tsk system call is issued from a handler, the READY task designated by the system call or the currently executed task enters the SUSPEND state. If a task in the WAIT state is placed in this situation, it goes into the WAIT-SUSPEND state.
The SUSPEND state is the condition in which a READY task or currently executed task is excluded from scheduling to halt processing due to I/O or other error occurrence. That is, when the SUSPEND request is made to a READY task, that task is excluded from the execution queue.
Note that no queue is formed for the SUSPEND request. Therefore, the SUSPEND request can only be made to the tasks in the RUN, READY, or WAIT state. If the SUSPEND request is made to a task in the SUSPEND state, an error code E_QOVR is returned.

5. WAIT-SUSPEND

When the SUSPEND request is made to a task in the WAIT state, that task goes into the WAIT-SUSPEND state. When the SUSPEND request is made to a task that is waiting for a request made by the wai_flg, wai_sem, or rcv_msg system call, that task remains in the request queue and simply goes into the WAIT-SUSPEND state.
When the wait condition for a task in the WAIT-SUSPEND state is cleared, that task goes into the SUSPEND state.
It is conceivable that the wait condition may be cleared, when any of the following conditions occurs.

- The task wakes up upon wup_tsk,or iwup_tsk system call issuance.
- The wait state task by dly_tsk, tslp_tsk system call issuance wakes up upon the period specified by tmout elapsing.
- The request of the task placed in wait state by wai_flg, wai_sem, rcv_msg, snd_mbf, rcv_mbf, cal_por, acp_por, get_blf, get_blk, vrcv_mbx system call is fullfilled.
- The WAIT state is forcibly cleared by the rel_wai or irel_wai system call

When the SUSPEND state clear request [17] is made to a task in the WAIT-SUSPEND state, that task goes into the WAIT state. Since a task in the SUSPEND state cannot request to be placed in the WAIT state, status change from SUSPEND to WAIT-SUSPEND does not possibly occur.

[17] rsm_tsk, irsm_tsk systemcall

6. DORMANT

This state refers to the condition in which a task is registered in the MR32R system but not activated. This task state prevails when either of the following two conditions occurs.

- The task is waiting to be activated.
- The task is normally terminated.[18] or forcibly terminated.[19]

7. NON-EXISTENT

The NON-EXISTENT state is a state in which no task is registered in the MR32R system as it is before a task is generated or as it is after a task has been deleted. A task, if generated, [20] is registered in the MR32R system and is put in the dormant state. This state is brought in two instances given below.

- An instance in which a task in the dormant state is deleted by another task. [21]
- An instance in which a task under execution terminates and deletes itself. [22]

[18] ext_tsk systemcall
[19] ter_tsk systemcall
[20] cre_tsk systemcall
[21] del_tsk systemcall
[22] exd_tsk systemcall

3.3.2 Task Priority and Ready Queue

In the real-time OS, several tasks may simultaneously request to be executed.
In such a case, it is necessary to determine which task the system should execute first. To properly handle this kind of situation, the system organizes the tasks into proper execution priority and starts execution with a task having the highest priority. To complete task execution quickly, tasks related to processing operations that need to be performed immediately should be given higher priorities.
The MR32R permits giving the same priority to several tasks. To provide proper control over the READY task execution order, the system generates a task execution queue call ed "ready queue."
The ready queue structure is shown in Figure 3.14[23]. The ready queue is provided and controlled for each priority level. The first task in the ready queue having the highest priority is placed in the RUN state. [24]

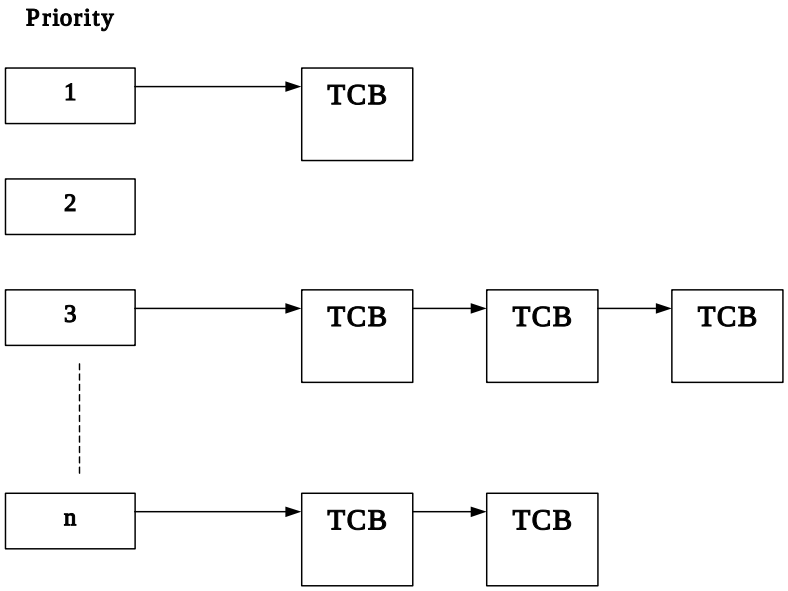


Figure 3.14 Ready Queue (Execution Queue)

[23] The TCB(task control block is described in the next chapter.)
[24] The task in the RUN state remains in the ready queue.

3.3.3 Task Control Block(TCB)

The task control block (TCB) refers to the data block that the real-time OS uses for individual task status, priority, and other control purposes.
The MR32R manages the following task information as the task control block

- Task connection pointer
  Task connection pointer used for ready queue formation or other purposes.
- Task status
- Task priority
- Task attribute
  The information of whether the stack area of the task is allocated in internal RAM or in external RAM storage area.
- Extended information
  Extended information of the task storage area.
- Task register information and other data[25] storage stack area pointer(current SP register value)
- Wake-up counter
  Task wake-up request storage area.
- Memory block size
  The request size of memory block storage area when the task is variable-size memory bloc wait state.
- Rendezvous wait bit pattern
  For rendezvous calls, the calling-side select condition bit pattern is stored in this area. When in an acceptance wait state, the acceptance select condition bit pattern is stored in this area.
- Flag wait mode
  This is a wait mode during event flag wait.
- Wait flag pattern
  If in a flag wait state, the flag's wait pattern is stored in this area.
- Time-out queue connection pointer
  Time-out queue connection pointer used for time-out queue formation.
- Time--out counter
  When a task is in a time--out wait state, the remaining wait time is stored.
- Exception mask
  Stores an exception mask value. This area is not allocated unless a forced exception handler is used [26].

The task control block is schematized in FIgure 3.15.

[25] Called the task context
[26] Define whether forced exception handler is used or not in the system definition of the configuration file.

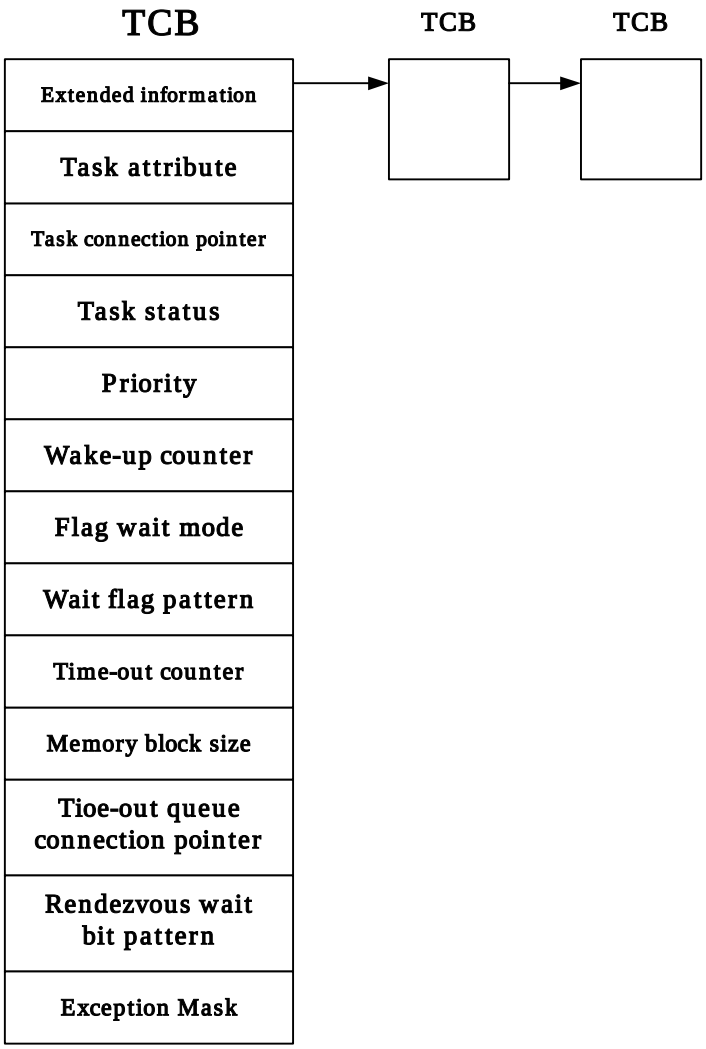


FIgure 3.15 Task control block

3.4 Handler

Difference between Tasks and Handlers
The tasks are program units that the MR32R executes and controls.Each task has its own independent context (program counter, stack pointer, status register, and other registers). Therefore, to transfer execution from one task to another [27] , it is necessary to effect context switching.
This processing operation takes time.Interrupt processing, which requires high-speed response, can be carried out by the MR32R without effecting context switching. That is, the interrupted task context (registers) can be used as is to run a program. This type of program is called the handler. As the handler uses the interrupted task context (registers) as is, it is always necessary to save the interrupted task context into memory at the beginning of the handler, and put the saved context back into the original position when returning to the task.

1. **Interrupt Handler**
   A program that starts upon hardware interruption is called the interrupt handler. MR32R activates interrupt handler after interrupt entry process. Interrupt entry process is done in the MR32R kernel. So, you can only register interrupt handlers in the configuration file.
2. **Cyclic Handler**
   This handler is a program that starts cyclically at preselected time intervals. The cyclic handler activity is to be changed[28] determine whether or not to validate a preset cyclic handler.
3. **Alarm Handler**
   This handler starts at preselected times.

The cyclic handler and alarm handler are called up by means of a subroutine call from the system clock interrupt (timer interrupt) handler (See Figure 3.16). Therefore, the cyclic handler and alarm handler function as part of the system clock interrupt handler. Note that the cyclic handler and alarm handler are called up under the conditions whose state is the system clock interrupt priority level.

[27] This transfer is called dispatching or switching
[28] act_cyc system call

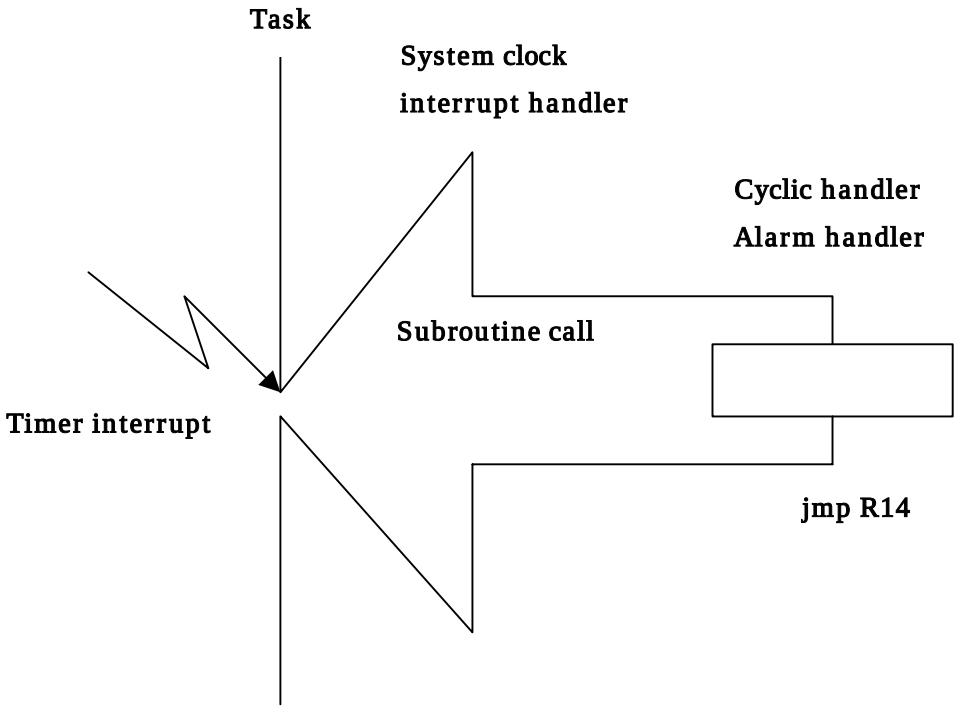


Figure 3.16 Cyclic Handler/Alarm Handler Activation

3.4.1 System Calls Exclusive for Handlers

In the MR32R, the following system calls can be issued from the handlers only. Note, however, that the ret_int system call is dedicated to the interrupt handler[29] and therefore cannot be issued from the cyclic handler or alarm handler.

Table 3.1System Calls Issuable from only Handlers

System call name		Function
ichg_pri	Change Task Priority	Changes the task priority.
irot_rdq	Rotate Ready Queue	Rotates the task ready queue.
irel_wai	Release Task Wait	Forcibly clears the task WAIT state.
isus_tsk	Suspend Task	Puts a task into the SUSPEND state.
irsm_tsk	Resume Task	Resumes the suspended task.
iwup_tsk	Wakeup Task	Wakes up the waiting task.
iset_flg	Set EventFlag	Sets an eventflag.
isig_sem	Signal Semaphore	Signal operation for a semaphore.
isnd_msg	Send Message to Mailbox	Sends a message.
ista_tsk	Start Task	Starts the task.
ret_int	Return from Interrupt Handler	Return from the interrupt handler.
visnd_mbx	Send Message	Sends a message.

[29] It isn't necessary to write this system call when specifying the interrupt handler as #pragma INTHANDLER in C language.

3.5 MR32R Kernel Structure

3.5.1 Module Structure

The MR32R kernel consists of the modules shown inFigure 3.17Each of these modules is composed of functions that exercise individual module features.
The MR32R kernel is supplied in the form of a library, and only necessary features are linked at the time of system generation. More specifically, only the functions used are chosen from those which comprise these modules and linked by means of the Linkage Editor. However, the scheduler module, part of the task management module, and part of the time management module are linked at all times because they are essential feature functions.
The applications program is a program created by the user.It consists of tasks, interrupt handler, alarm handler, and cyclic handler.[30]

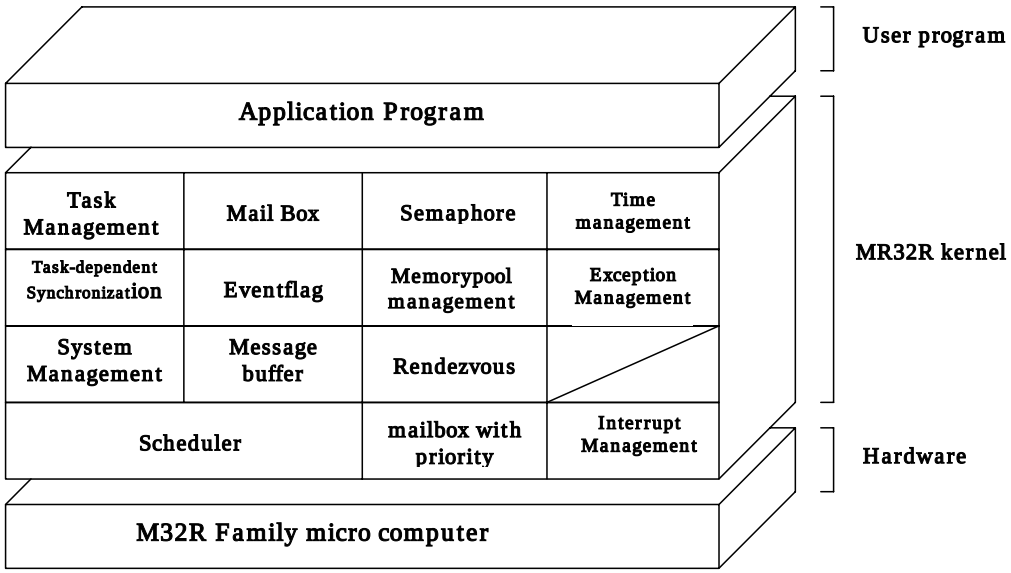


Figure 3.17 MR32R Structure

[30] For details, See 3.5.10

3.5.2 Module Overview

The MR32R kernel modules are outlined below.

- **Scheduler**
  Forms a task processing queue based on task priority and controls operation so that the high-priority task at the beginning in that queue (task with small priority value) is executed.

- **Task Management Module**
  Exercises the management of various task states such as the RUN, READY, WAIT, and SUSPEND state

- **Task Synchronization Module**
  Accomplishes inter-task synchronization by changing the task status from a different task.

- **Interrupt Management Module**
  Makes a return from the interrupt handler

- **Time Management Module**
  Sets up the system timer used by the MR32R kernel and starts the user-created alarm handler[31] and cyclic handler.[32]

- **System Management Module**
  Reports the MR32R kernel version number or other information.

- **Sync/Communication Module**
  This is the function for synchronization and communication among the tasks. The following three functional modules are offered.
  - ♦ Eventflag
    Checks whether the flag controlled within the MR32R is set up and then determines whether or not to initiate task execution. This results in accomplishing synchronization between tasks.
  - ♦ Semaphore
    Reads the semaphore counter value controlled within the MR32R and then determines whether or not to initiate task execution. This also results in accomplishing synchronization between tasks.
  - ♦ Mailbox
    Provides inter-task data communication by delivering the first data address.

- Extended synchronization and communication
  This function is provided to synchronize operation between tasks and perform intertask communication. Following two functional modules are available:
  - ♦ Messagebuffer
    Performs intertask synchronization and communication simultaneously. Unlike the mailbox, this function allows variable-size messages to be copied before being transmitted or received.
  - ♦ Rendezvous
    Adjusts timing between tasks by keeping messages waiting as necessary.

[31] This handler actuates once only at preselected times.
[32] This handler periodically actuates.

- Memorypool Management Function
  Provides dynamic allocation or release of a memory area used by a task or a handler.

- Inplementation Dependent Function
  Provides forced exception function and resetting OS resources Function.

- Inplementation Dependent Function(mailbox with priority)
  Provides mailbox with priority Function.

3.5.3 Task Management Function

The task management function is used to perform task operations such as task start/stop and task priority updating. The MR32R kernel offers the following task management function system calls.

- Creates a task (cre_tsk)
  Creates a task having an ID some other task appoints.

- Delete aTask (del_tsk)
  Deletes a task having an ID some other task appoints. The state of the task deleted is switched from dormant to nonexistent, and releases the stack area.

- Terminates and deletes a task itself (exd_tsk)
  Puts a task itself to normal termination and deletes it. That is, puts a task itself in the nonexistent state, and releases the stack area.

- Starting the Task (sta_tsk)
  Starts the task, changing its status from DORMANT to either READY or RUN.

- Starting the Task from the handler (ista_tsk)
  By activating a task from the handler, the status of the task to be activated is changed from the DORMANT state to either READY or RUN.

- Ending Its Own Task (ext_tsk)
  Ends its own task and places it in the DORMANT state, so that this task will not be executed until activated again.

- Forcibly Terminating Some Other Task (ter_tsk)
  Forcibly terminates a different task placed in a state other than DORMANT and places it in the DORMANT state.
  When the forcibly terminated task is activated again, it acts as if it is reset (See Figure 3.18).

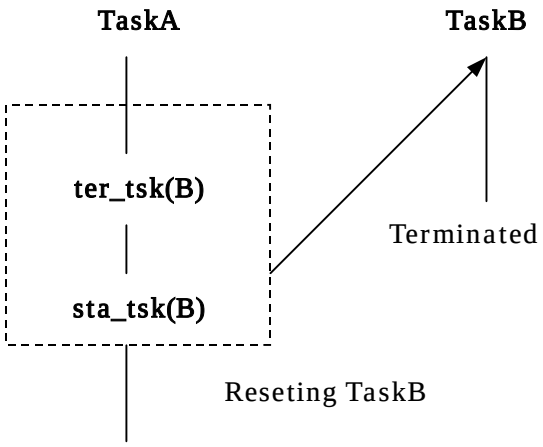


Figure 3.18 Task Resetting

- Changing the Task Priority (chg_pri, ichg_pri)
  Changes the task priority, and if the task is in the READY or RUN state, updates the ready queue also (See Figure 3.19).

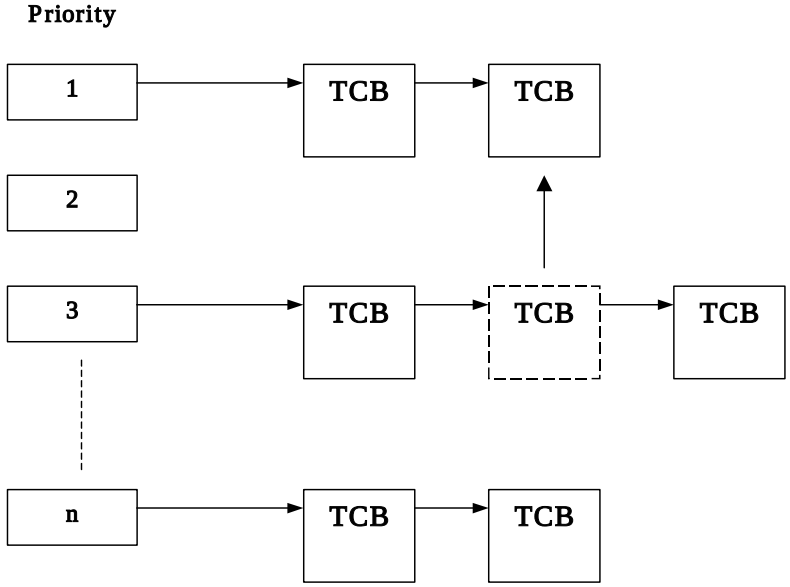


Figure 3.19 Priority Change

- Rotating the Ready Queue (rot_rdq, irot_rdq)
  This system call establishes the TSS (time-sharing system). That is, if the ready queue is rotated at regular intervals, round robin scheduling required for the TSS is accomplished (See Figure 3.20).

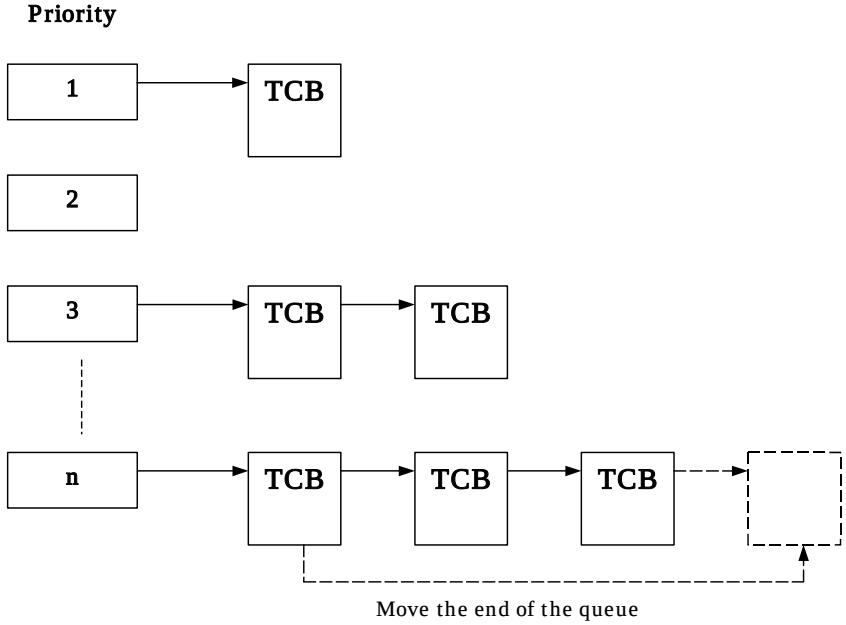


Figure 3.20 Ready Queue Management by rot_rdq System Call

- Forcibly Clearing the Task WAIT State (rel_wai, irel_wai)
  Forcibly clears the task WAIT state. The WAIT state tasks to be cleared by this system call are those which have entered the WAIT state under the following conditions.
  - Time-out wait state
  - Time-out wait state by slp_tsk
  - Eventflag wait (+ time-out) state
  - Semaphore wait (+time-out) state
  - Message wait (+time-out) state
  - Send message wait (+time-out) state (message buffer)
  - Recieve message wait (+time-out) state (message buffer)
  - Call wait (+time-out) state (rendezvous)
  - Recieve wait (+time-out) state (rendezvous)
  - Memory block allocation wait (+time-out) state (fixed-size or variable size)
  - Message wait (+time-out) state(mailbox with priority function)

- Acquiring Its Own ID (get_tid)
  Acquires its own task ID number. When this system call is issued from a handler, 0(zero) is obtained instead of the ID number.

- Referencing a task's status (ref_tsk)
  Referencing a task's status or priority etc.

3.5.4 Synchronization functions attached to task

The task-dependent synchronization functions attached to task is used to accomplish synchronization between tasks by placing a task in the WAIT, SUSPEND, or WAIT-SUSPEND state or waking up a WAIT state task.
The MR32R offers the following task incorporated synchronization system calls.

- Placing a Task in the SUSPEND State (sus_tsk, isus_tsk)
- Restarting a Task Placed in SUSPEND State (rsm_tsk, irsm_tsk)
  Forcibly suspends or resumes task execution. If a READY task is forced to wait, it enters the SUSPEND state. If a WAITING state task is forcibly suspended, it enters the WAIT-SUSPEND state (See Figure 3.21).

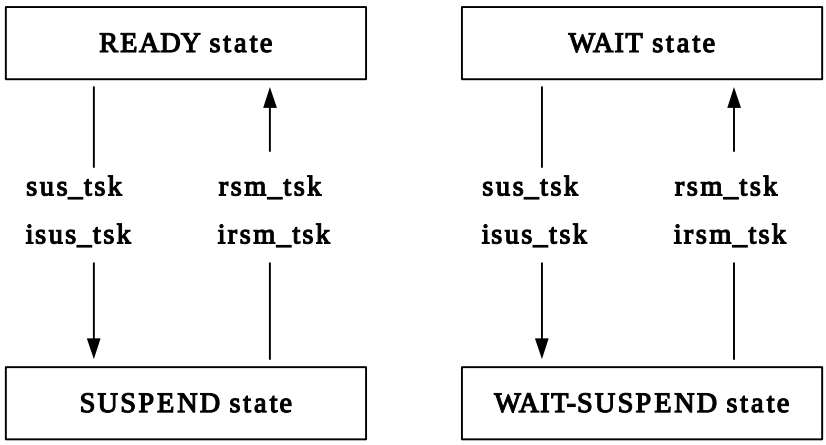


Figure 3.21 Suspending and Resuming a Task

- Placing a Task in the WAIT State (slp_tsk,tslp_tsk)

- Waking up wait state task (wup_tsk, iwup_tsk)
  Wakes up a task that has been placed in a WAIT state by the slp_tsk,tslp_tsk system call.
  No task can be waked up unless they have been placed in a WAIT state by. [33]
  If tasks that have been placed in a WAIT state for other conditions than the slp_tsk or tslp_tsk system call or tasks in other states except one that is in a DORMANT state are waked up by the wup_tsk or iwup_tsk system call, it results in only wakeup requests being accumulated. Therefore, if a wakeup request is issued for a task in executing state, for example, that wake-up request is stored in memory temporarily. Then when the task in that executing state is placed in a wait state by the slp_tsk system call, the accumulated wakeup request becomes valid, so the task is executed continuously without being placed in a wait state. (See Figure 3.22)

- Canceling a Task Wake-up Request (can_wup)
  Clears the stored wake-up reques.(See Figure 3.23).

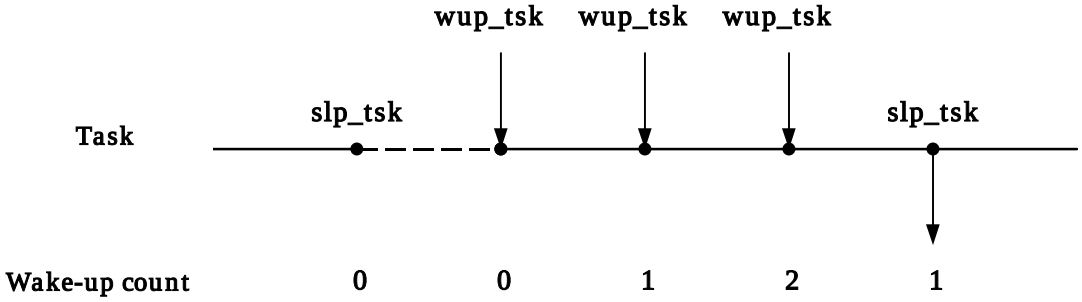


Figure 3.22 Wake-up Request Storage

[33] If the task is WAIT state ,it is not waked-up in any condition as below.
- Eventflag waiting
- Semaphore Waiting
- Message waiting
- Timeout waiting
- Fixed-size memoryblock waiting
- Variable-size memorypool waiting
- Port accept waiting
- Port call waiting
- Rendesvouz waiting
- Message buffer receive waiting
- Message buffer send waiting
- Message waiting for mailbox with priority

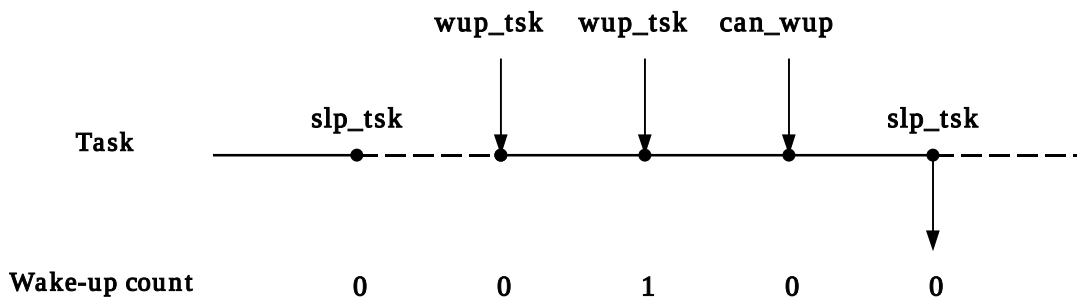


Figure 3.23 Wake-up Request Cancellation

3.5.5 Eventflag

The eventflag is an internal facility of MR32R that is used to synchronize the execution of multiple tasks. The eventflag uses a flag wait pattern and a 32-bit pattern to control task execution. A task is kept waiting until the flag wait conditions set are met.
The MR32R kernel offers the following eventflag system calls.

- Create eventflag (cre_flg)
  Creates an eventflag with the ID specified by a task.

- Delete eventflag (del_flg)
  Deletes an eventflag with the ID specified by a task.

- Setting the Eventflag (set_flg, iset_flg)
  Sets the eventflag so that a task waiting the eventflag is released from the WAIT state.

- Clearing the Eventflag (clr_flg)
  Clearing the Eventflag.

- Waiting for eventflag (wai_flg, twai_flg)
  Waits until the eventflag is set to a certain pattern. There are three modes as listed below in which the eventflag is waited for.
  - ♦ AND wait
    Waits until all specified bits are set.
  - ♦ OR wait
    Waits until any one of the specified bits is set.
  - ♦ Clear specification
    Clears the flag when the AND wait or OR wait condition is met.

- Getting eventflag (pol_flg)
  Examines whether the eventflag is in a certain pattern. In this system call, tasks are not placed in a wait state.

- Obtaining the eventflag's status (ref_flg)

References the bit pattern of the relevant eventflag and checks whether a waiting task is present.
Figure 3.24 shows an example of task execution control by the eventflag using the wai_flg and set_flg system calls.
The eventflag has a feature that it can wake up multiple tasks collectively at a time.
In Figure 3.24, there are six tasks linked one to another, task A to task F. When the flag pattern is set to 0xF by the set_flg system call, the tasks that meet the wait conditions are removed sequentially from the top of the queue. In this diagram, the tasks that meet the wait conditions are task A, task C, task E, and task F. Out of these tasks, task A, task C, and task E are removed from the queue. However, since task E is waiting in clear specification, the flag is cleared when task E is remove from the queue. Therefore, task F is not removed from the queue.

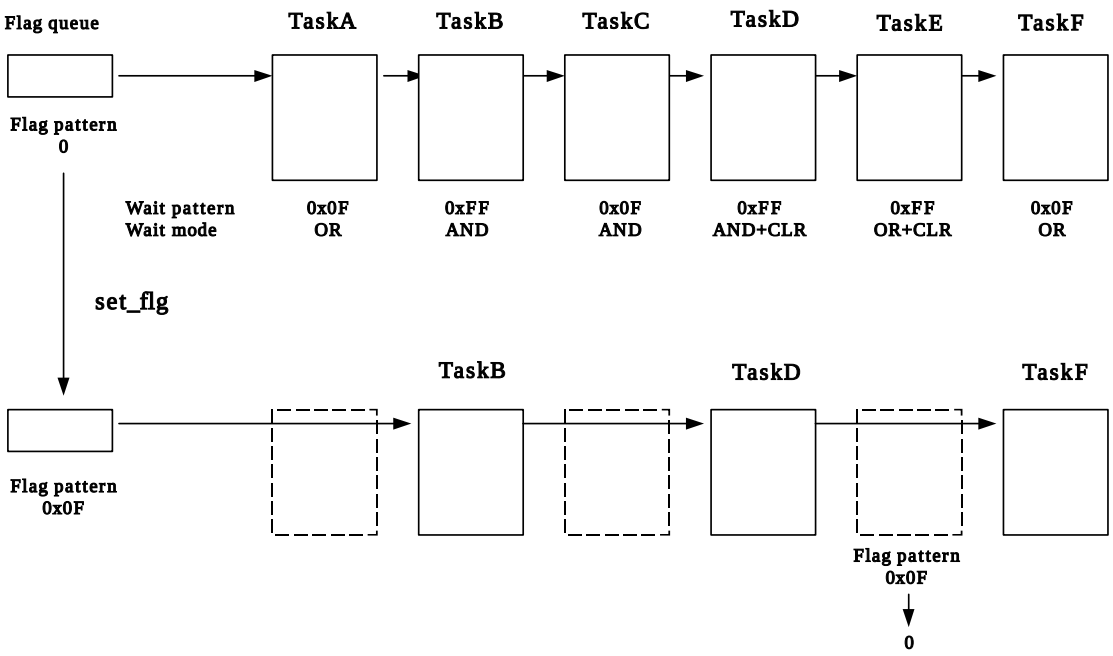


Figure 3.24 Task Execution Control by the Eventflag

3.5.6 Semaphore

The semaphore is a function executed to coordinate the use of devices and other resources to be shared by several tasks in cases where the tasks simultaneously require the use of them. When, for instance, four tasks simultaneously try to acquire a total of only three communication lines as shown in Figure 3.25 , communication line-to-task connections can be made without incurring contention.

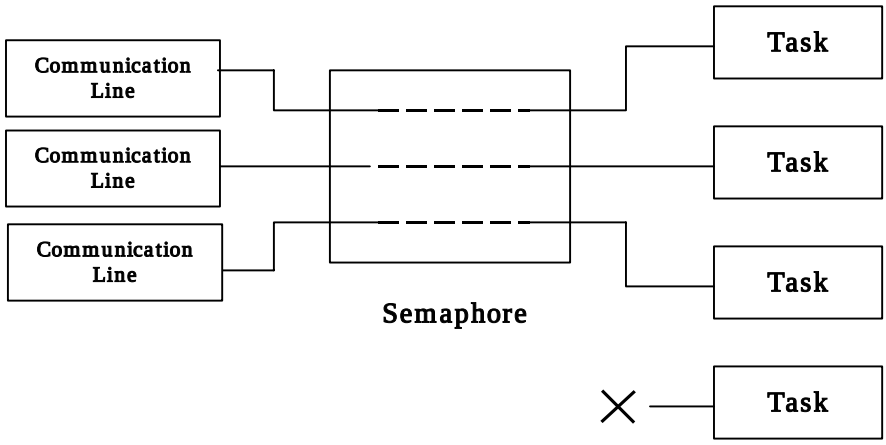


Figure 3.25 Exclusive Control by Semaphore

The semaphore has an internal semaphore counter. In accordance with this counter, the semaphore is acquired or released to prevent competition for use of the same resource.(See Figure 3.26).

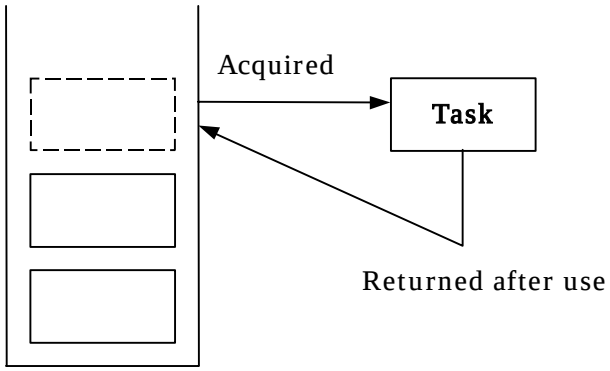


Figure 3.26 Semaphore Counter

The MR32R kernel offers the following semaphore synchronization system calls.

- Creates a semaphore (cre_sem)
  Creates a semaphore having an ID some other task appoints.

- Deletes a semaphore (del_sem)
  Deletes a semaphore having an ID some other task appoints.

- Signaling the Semaphore (sig_sem, isig_sem)
  Sends a signal to the semaphore. This system call wakes up a task that is waiting for the semaphores service, or increments the semaphore counter by 1 if no task is waiting for the

semaphores service.

- Acquiring the Semaphore (wai_sem, twai_sem)
  Waits for the semaphores service. If the semaphore counter value is 0 (zero), the semaphore cannot be acquired. Therefore, the WAIT state prevails.

- Acquiring the Semaphore (preq_sem)
  Acquires the semaphore. If there is no semaphore to acquire, an error code is returned and the WAIT state does not prevail.

- Referencing the semaphore's status (ref_sem)
  Checks the status of the target semaphore. Checks the count value and existence of the wait task for the target semaphore.
  Figure 3.27 shows example task execution control provided by the wai_sem and sig_sem systemcalls.

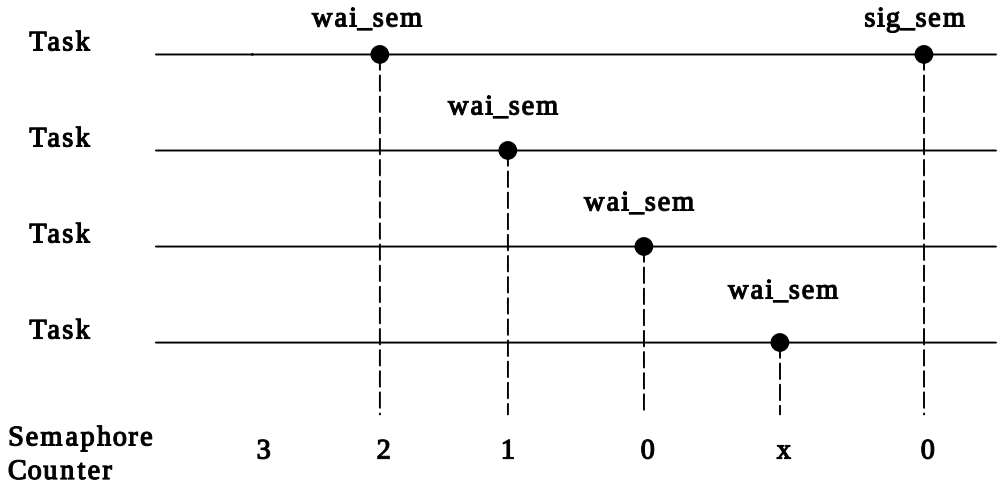


Figure 3.27 Task Execution Control by Semaphore

3.5.7 Mailbox

The mailbox is a mechanism that provides data communication between tasks. A typical example is presented in Figure 3.28. In this example, after task A sends a message in the mailbox, task B can obtain the message from the mailbox.

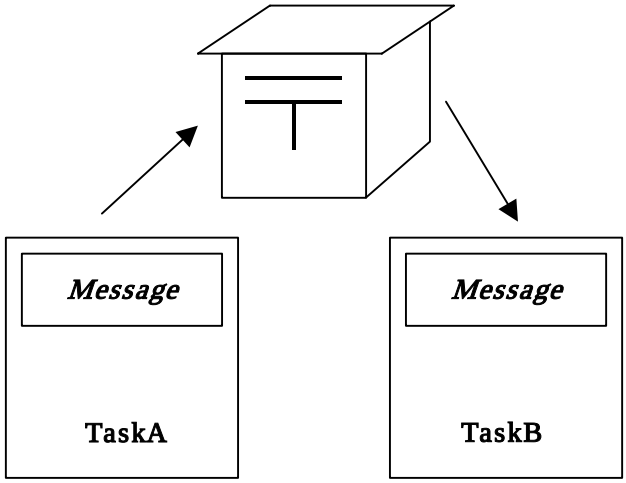


Figure 3.28 Mailbox

The messages that can be placed into this mailbox are 32-bit data
Standard specifications are such that MR32R uses this data as the start address of a message packet.[34] However, this data can be used simply as ordinary data.[35]

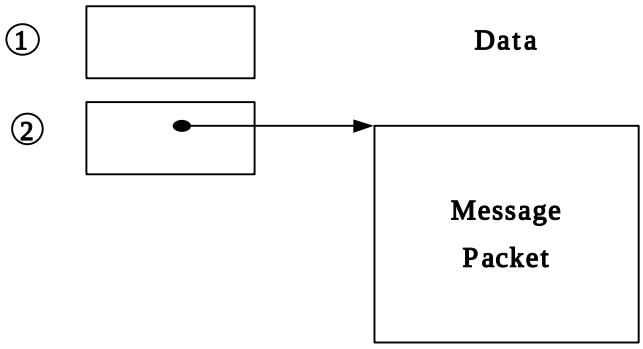


Figure 3.29 Meaning of Message

The mailbox is capable of storing messages. Stored messages are retrieved on the FIFO basis.[36]However, the number of messages that can be stored in the mailbox is limited. The maximum number of messages that can be stored in the mailbox is referred to as the Message queue size (See Figure 3.30).

[34] According to the standard stated in ITRON Specification,this data is to be used as the message packet first address.
[35] In this case,Cast to the data of argument of the system call to convert into pointer types.
[36] First in,first out.

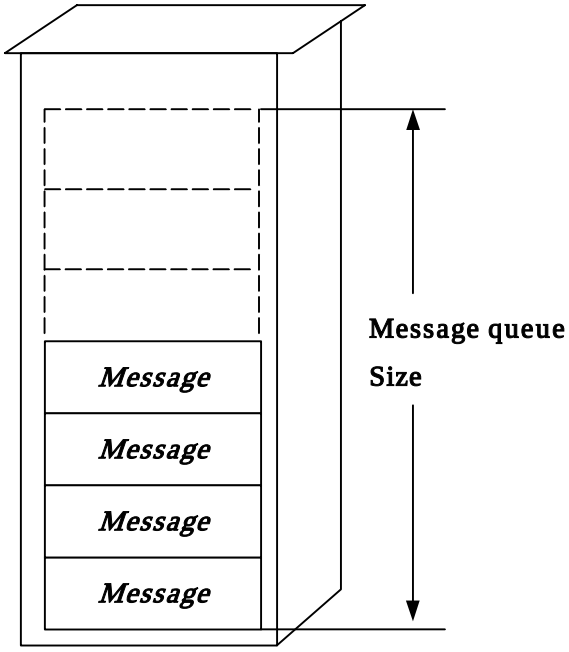


Figure 3.30 Message queue Size

The MR32R kernel offers the following mailbox system calls.

- Creates a mailbox (cre_mbx)
  Creates a mailbox having an ID some other task appoints.

- Deletes a mailbox (del_mbx)
  Deletes a mailbox having an ID some other task appoints.

- Transmitting a Message (snd_msg, isnd_msg)
  Sends a message or puts a message into the mailbox.

- Receiving a Message (rcv_msg, trcv_msg)
  Receives a message or obtains a message from the mailbox. If the message is not in the mailbox, the WAIT state prevails until the message is put in the mailbox.

- Receiving a Message (prcv_msg)
  Receives a message. This system call differs from the rcv_msg system call in that the former returns an error code without incurring the WAIT state if the message is not found in the mailbox.

- Referencing the mailbox's status (ref_mbx)
  Checks whether tasks are present that are waiting for a message to be sent in the relevant mailbox, and references the first message in the mailbox.

3.5.8 Messagebuffer

The messagebuffer accomplishes synchronization and communication simultaneously by passing messages as in the case of the mailbox function. The difference with the mailbox is that it is a copy of the message content that is transmitted to the receiving task.

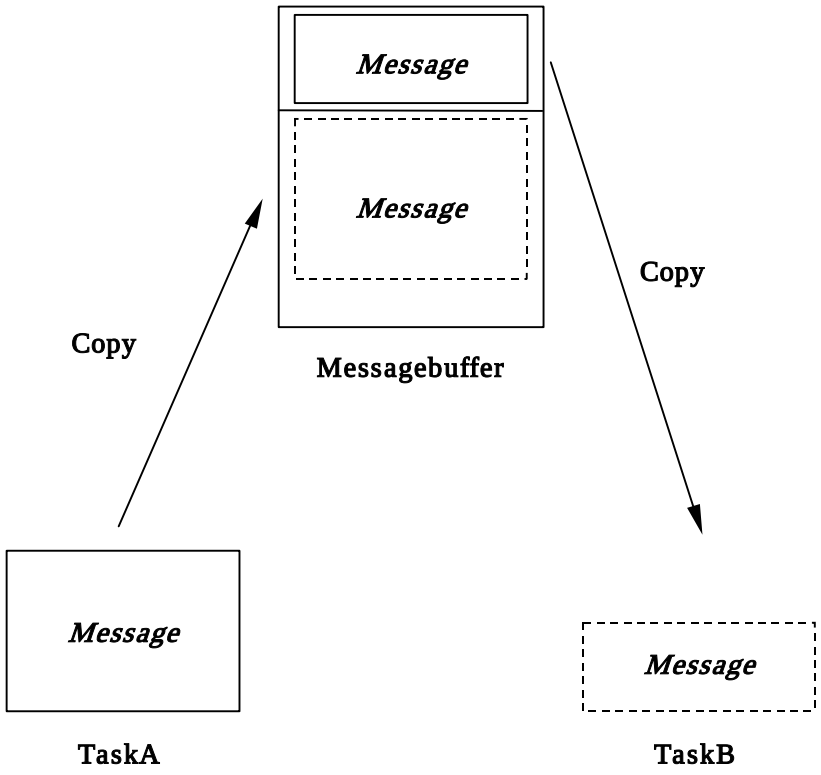


Figure 3.31 Messagebuffer

As shown in Figure 3.31, the messagebuffer has messages stored in it in the same way as with the mailbox. The stored messages are retrieved sequentially in order of FIFO.

When sending a message using message buffer functions, M3T-MR32R writes 4-byte size information first and then the message body into the ring buffer. If the previously transmitted message did not end at a 4-byte boundary, the size info of the message next to be sent is written from the next 4-byte boundary.

So, a transmit message consumes alignment adjust + 4-byte size info + message body (in bytes) in the buffer memory. Note that no receive messages contain size information.

[Example]
When message B of 12 bytes wide is sent after message A that was not completed at a 4-byte boundary, the size info of message B is first written from the next 4-byte boundary and then the body of message B is written successively.

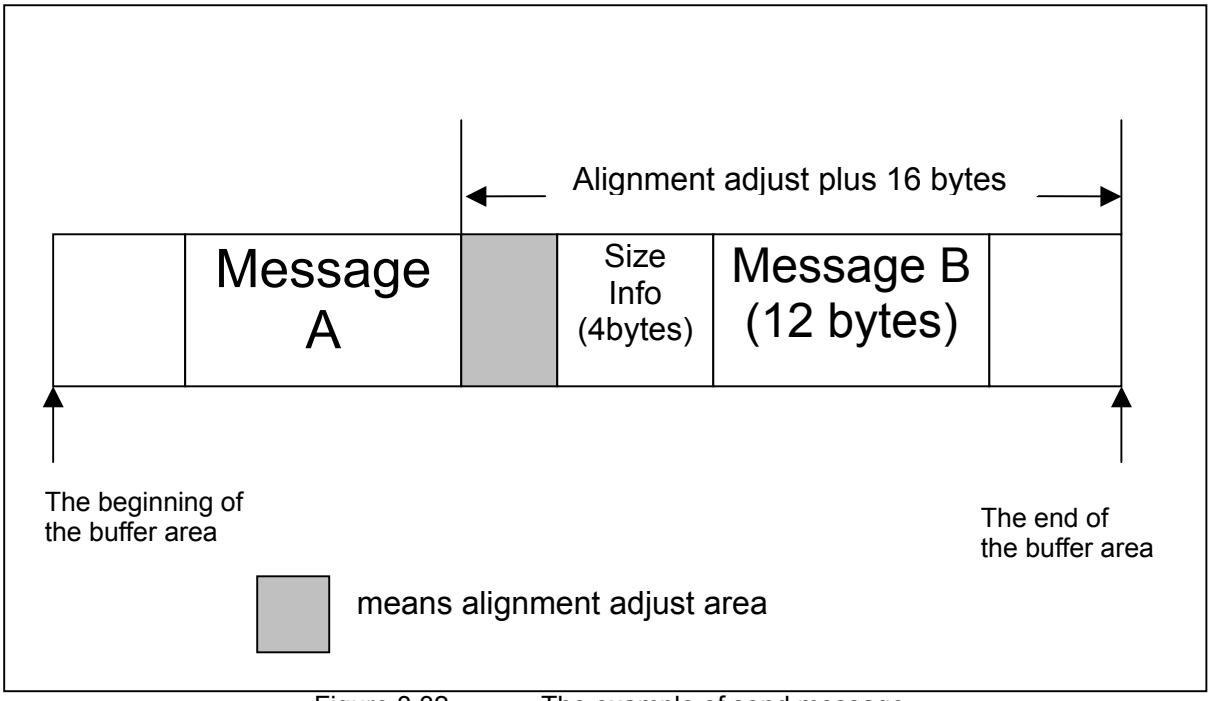

Alignment adjust plus 16 bytes
Message A
Size Info (4bytes)
Message B (12 bytes)
The beginning of the buffer area
The end of the buffer area
means alignment adjust area

Figure 3.32 The example of send message

There are following messagebuffer system calls that are provided by the MR32R kernel:

- Create messagebuffer (cre_mbf)
  Creates a messagebuffer with the ID specified by a task.

- Delete messagebuffer (del_mbf)
  Deletes a messagebuffer with the ID specified by a task.

- Send message (snd_mbf, tsnd_mbf)
  Transmits a message to the messagebuffer. Namely, a message is copied to the message-buffer. The messages transferred to the messagebuffer come in varying sizes. Depending on the free space in the messagebuffer, messages may be or may not be transferred. If the free space in the messagebuffer is insufficient, the message is kept waiting for transmission. (See Figure 3.33).

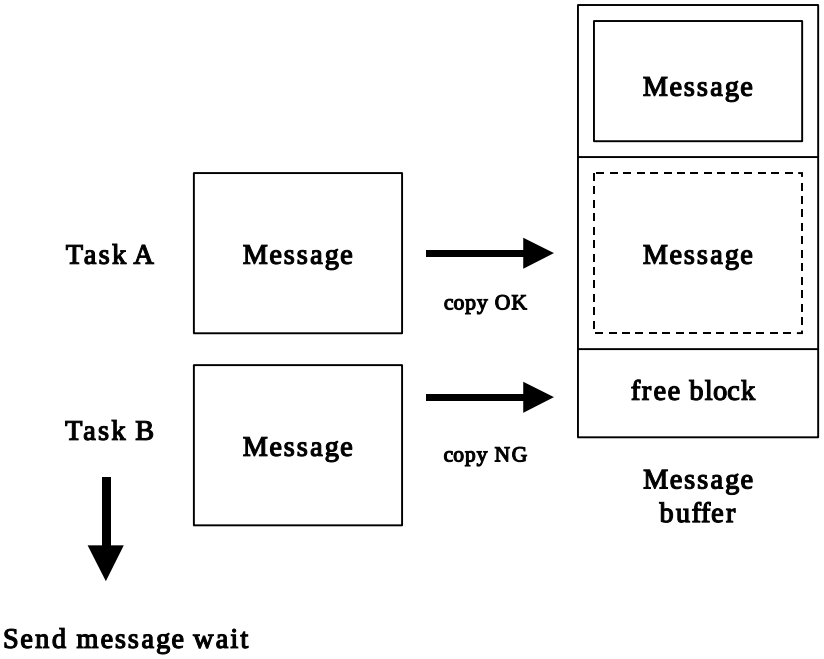


Figure 3.33 Send Message

- Send message (psnd_mbf)
  Transmits a message to the messagebuffer. The difference with snd_mbf and tsnd_mbf is that when the free space in the messagebuffer is insufficient, this system call returns error code without keeping the message waiting for transmission[37].

[37] An error code E_TMOUT is returned.

- Receive message (rcv_mbf, trcv_mbf)
  Receives a message. A message is retrieved from the messagebuffer. If no message exists in the messagebuffer, this system call goes to a receive wait state.
  When a message is received from the messagebuffer, the free space in the messagebuffer increases that much. If there is any task kept waiting for transmission and the size of the message to be transmitted by that task is smaller than the free space in the messagebuffer, the message is sent to the messagebuffer and the task goes to an execution (RUN) or executable (READY) state.

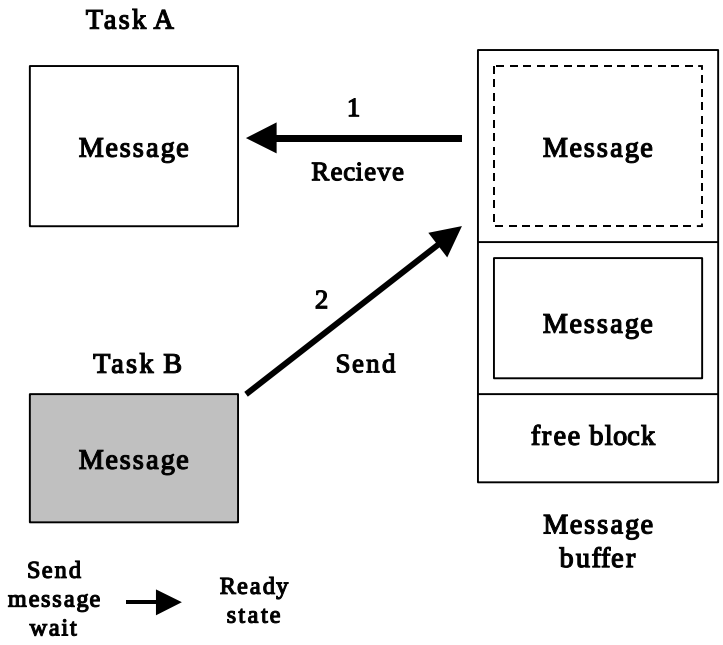


Figure 3.34 Receive Message

When task A is in the execution (RUN) state and task B is in wait state, as in Figure 3.34.

1. **Task A receives a message from the messagebuffer.**
   As a message is received from the messagebuffer, the free space in the messagebuffer increases that much.

2. **Task B transmits a message to the messagebuffer.**
   Task B which has been kept waiting for transmission because the free space in the messagebuffer was insufficient now transmits a message to the messagebuffer as task A has received a message. The status of task B changes from the transmit wait state to an executable state.

- Receive message (prcv_mbf)
  Receives a message. The difference with rcv_mbf and trcv_mbf is that when no message exists in the messagebuffer, this system call returns error code without going to a receive wait state [38].

- Reference messagebuffer status (ref_mbf)

[38] An error code E_TMOUT is returned.

Checks the target messagebuffer to see if there is any task kept waiting for transmission or waiting for reception, as well as find the size of the next message to be received.

3.5.9 Rendezvous

The rendezvous function keeps a task (call) and a task (accept) waiting each other through a window called the "port" and when rendezvous is established, exchanges messages between the tasks. Establishment of rendezvous means that when the AND'ed result of the calling-side bit pattern and receiving-side bit pattern is not 0, rendezvous is assumed to have been established.
This function is useful for server and client implementation on the real-time OS.

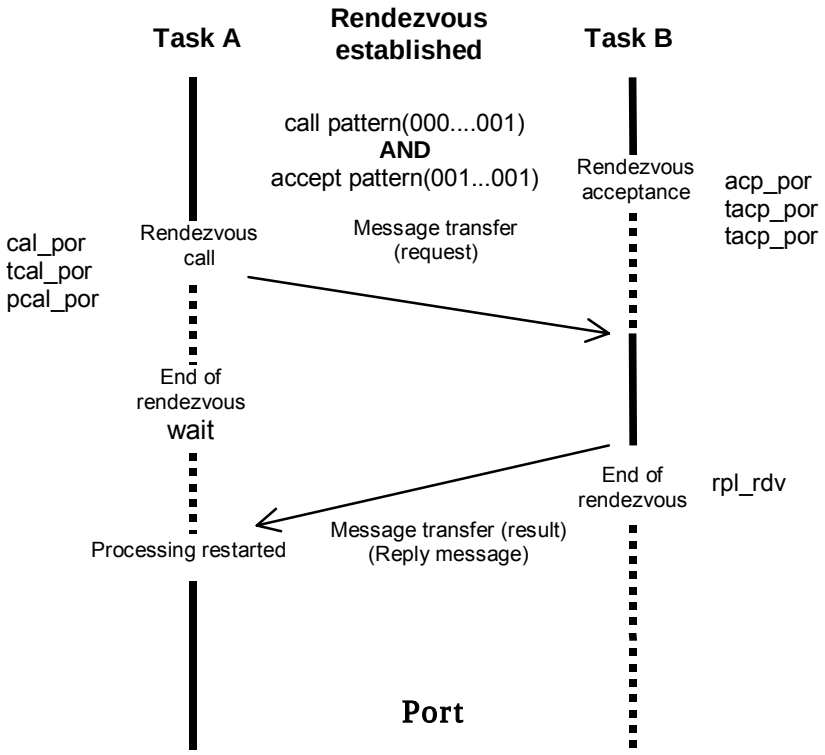


Figure 3.35 Rendezvous

There are following rendezvous system calls that are provided by the MR32R kernel:

- Create rendezvous port (cre_por)
  Creates a rendezvous port with the ID specified by a task.

- Delete rendezvous port (del_por)
  Deletes a rendezvous port with the ID specified by a task.

- Make rendezvous call to port (cal_por, tcal_por)
  Issues a cal_por or tcal_por system call to check whether rendezvous with the task in the acceptance wait state at the specified port will be established. When rendezvous is established, a message is transferred to the task in the acceptance wait state and the task goes from the acceptance wait state to an executable state.
  If no task exists that is kept waiting for acceptance at the specified port, or although there is a task waiting for acceptance, rendezvous establishment condition is not met, the task that issued cal_por or tcal_por is placed in a call wait state, so it is queued up in the call waiting queue.

- Make rendezvous call to port (pcal_por)

Performs the same processing as with the cal_por and tcal_por system calls, except that if no task exists that is kept waiting for acceptance at the specified port, or although there is a task waiting for acceptance, rendezvous establishment condition is not met, the issuing task only returns error code without going to a call wait state.

- Accept rendezvous call from port (acp_por, tacp_por)
  Issues a acp_por or tacp_por system call to check whether rendezvous with the task in the call wait state at the specified port will be established. When rendezvous is established, the task kept in the call wait state is removed from the call wait queue and goes to an end of rendezvous wait state. Note that the task on the rendezvous acceptance side (the task that issued acp_por) can perform multiple rendezvous sessions simultaneously. Figure 3.35 shows multiple rendezvous sessions at different ports. It is also possible to perform multiple rendezvous sessions at the same port.
  If no task exists that is kept waiting for call at the specified port, or although there is a task waiting for call, rendezvous establishment condition is not met, the task that issued acp_por or tacp_por is placed in an acceptance wait state, so it is queued up in the acceptance wait queue.

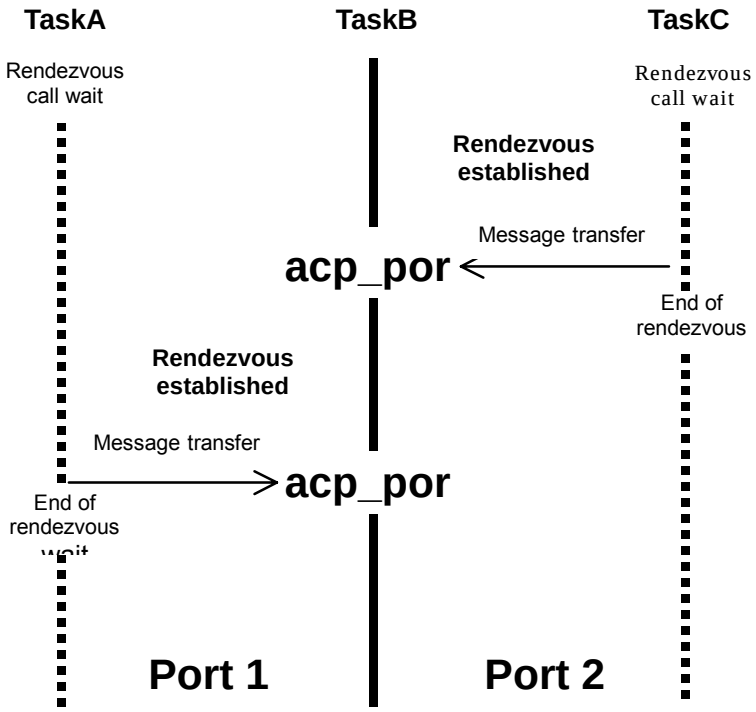


Figure 3.36 Multiple rendezvous sessions

- Accept rendezvous call from port (pacp_por)
  Performs the same processing as with the acp_por and tacp_por system calls, except that if no task exists that is kept waiting for call at the specified port, or although there is a task waiting for call, rendezvous establishment condition is not met, the issuing task only returns error code without going to an acceptance wait state.

- Forward rendezvous to port (fwd_por)
  When this system call (fwd_por) is issued, the task currently in rendezvous session with the

calling task is released from the rendezvous state and a rendezvous call is made to a specified another port. (This system call must always be issued after executing the acp_por, tacp_port, or pacp_por system call.) After rendezvous forwarding, the same processing as with the cal_por, tcal_por, or pcal_por system call is performed.

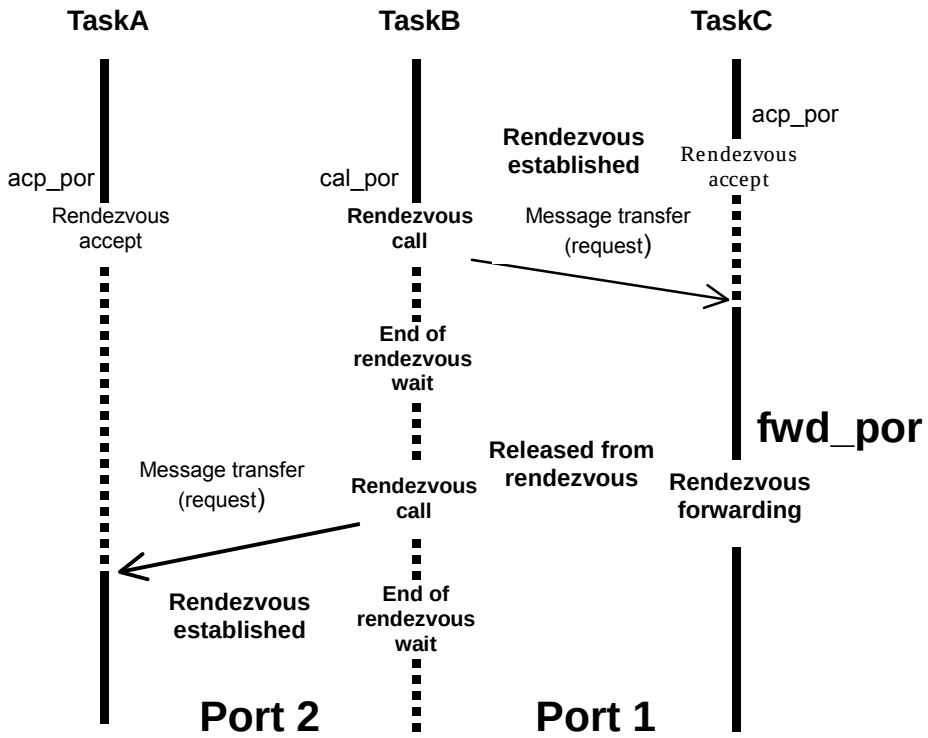


Figure 3.37 Rendezvous forwarding

- Rendezvous reply (rpl_rdv)
  When this system call (rpl_rdv) is issued, a reply message is returned to the calling task before terminating rendezvous. This system call can only be executed after issuing the acp_por, tacp_port, or pacp_por system call. Upon receiving the reply message, the calling task goes from the rendezvous wait state to an executable state.

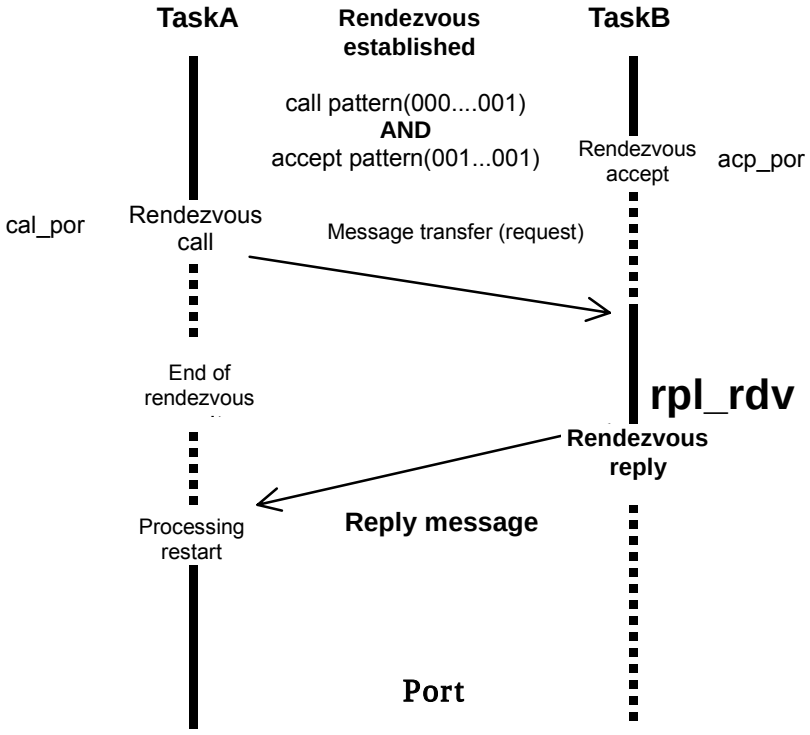


Figure 3.38 Rendezvous reply

- Reference rendezvous port (ref_por)
  Checks the rendezvous port of the specified ID to see if there is any task waiting for call or waiting for acceptance.

3.5.10 Interrupt Management Function

The interrupt management function provides a function to process requested external interrupts in real time.
The interrupt management system calls provided by the MR32R kernel include the following:

- Define interrupt handler (def_int)
  Defines an interrupt handler in the specified interrupt vector.

- Return from interrupt handler (ret_int)
  When returning from the interrupt handler, this ret_int system call starts the scheduler to switch over the tasks as necessary.
  The interrupt management function is automatically called at end of the handler function. In this case, therefore, this system call does not need to be called.

- Disabling interrupts and task dispatch (loc_cpu)
  The loc_cpu system call disables interrupts and task dispatch.

- Enabling interrupts and task dispatch (unl_cpu)
  The (unl_cpu) system call enables external interrupts and task dispatch. Therefore, this system call re-enables the interrupts and task dispatch that have been disabled by the loc_cpu system call.

Figure 3.39 shows an interrupt processing flow. Processing a series of operations from task selection to register restoration is called a "scheduler."

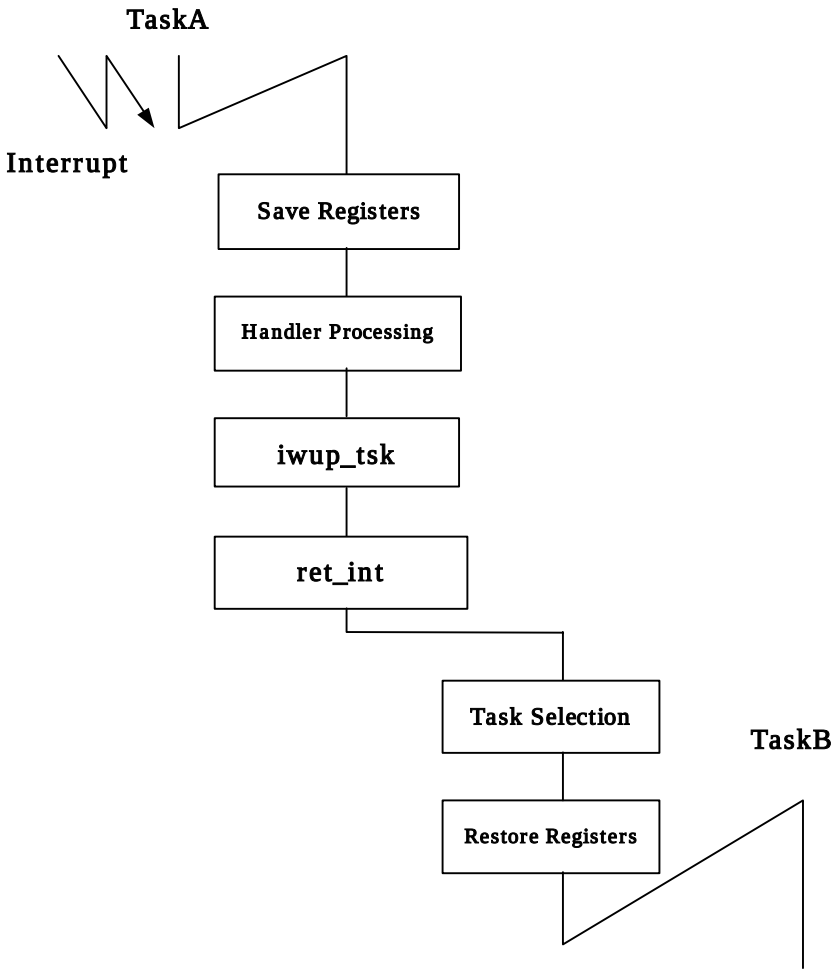


Figure 3.39 Interrupt process flow

3.5.11 Memorypool Management Function

The memorypool management function provides system memory space (RAM space) dynamic control.
This function is used to manage a specific memory area (memorypool), dynamically obtain memory blocks from the memorypool as needed for tasks or handlers, and release unnecessary memory blocks to the memorypool.
The MR32R supports two types of memorypool management functions, one for fixed-size and the other for variable-size.

Fixed-size Memorypool Management Function
You specify memory block size using configuration file.
The MR32R kernel offers the following Fixed-size memorypool management system calls.

- Creates a fixed-size memorypool (cre_mpf)
  Creates a fixed-size memorypool having an ID some other task appoints.

- Deletes a fixed-size memorypool (del_mpf)
  Deletes a fixed-size memorypool having an ID some other task appoints.

- Get memory block (get_blf, tget_blf)
  Acquires a memory block from the fixed-size memorypool of the specified ID. If no free memory block exists in the specified fixed-size memorypool, the task that issued this system call goes to a wait state, so it is queued up in the wait queue.

- Get memory block (pget_blf)
  Acquires a memory block from the fixed-size memorypool of the specified ID. The difference with get_blf and tget_blf is that when no free memory block exists in the memorypool, the issuing task only returns error code without going to a wait state.

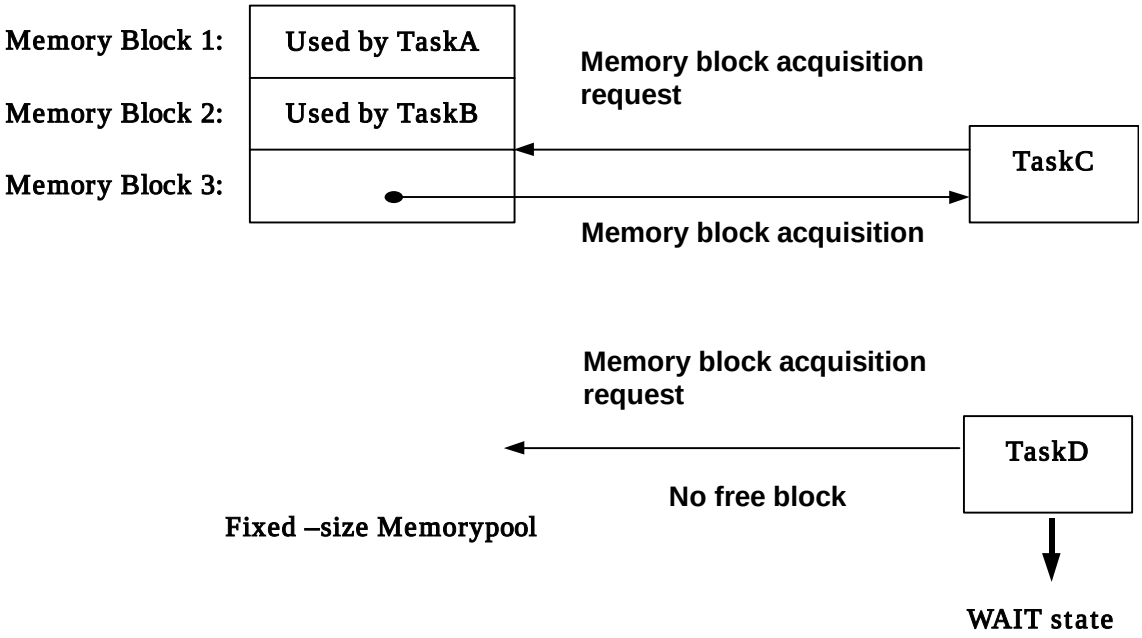


Figure 3.40 Fixed-size Memorypool Management

- Releasing a Memory Block (rel_blf)
  Releases the memory block obtainedby the task.If there is a task being memory block allocation wait state, rel_blf system call allocates memory block to the task which is top of the queue.In this case, the task is moved to ready state.
  Also, If there is no task being memory block allocation wait state, rel_blf system call release memory block.

- Referencing the memorypool's status (ref_mpf)
  References the number of blank blocks of the relevant memorypool and their sizes.

Variable-size Memorypool Management Function

The technique that allows you to arbitrary define the size of memory block acquirable from the memorypool is termed Variable-size scheme. The MR32R manages memory in terms of four fixed-size memory block sizes.

The MR32R calculates the size of individual blocks based on the maximum memory block size to be acquired. You specify the maximum memory block size using the configuration file.

```
e.g.

    variable_memorypool[]{03-5403-0899

            max_memsize     = 400; <---- Maximum size

            heap_size       = 5000;

    };
```

Defining a variable-size memorypool as shown above causes four fixed-size memory block sizes to become 60 bytes, 120 bytes, 240 bytes, and 480 bytes in compliance with max_memsize.

In the case of user-requested memory, the MR32R performs calculations based on the specified size and selects and allocates the optimum one of four fixed-size memory block sizes. The MR32R cannot allocate a memory block that is not one of the four sizes.

The size of the four fixed-sized memory block can be calculated as below.

a = (((max_memsize + (12-1))/96)+1)*12
b = a*2
c = a*4
d = a*8

System calls the MR32R provides include the following.

- Create variable-size memorypool (cre_mpl)
  Creates a variable-size memorypool with the ID specified by a task.

- Delete variable-size memorypool (del_mpl)
  Deletes a variable-size memorypool with the ID specified by a task.

- Get memory block (get_blk, tget_blk)
  Acquires a memory block from a variable-size memorypool. The four types of block sizes are rounded off to the nearest optimum block size and a block of the rounded size is acquired from the memorypool. If no free memory block of the specified size exists in the memorypool, the task that issued this system call goes to a wait state, so it is queued up in the wait queue.

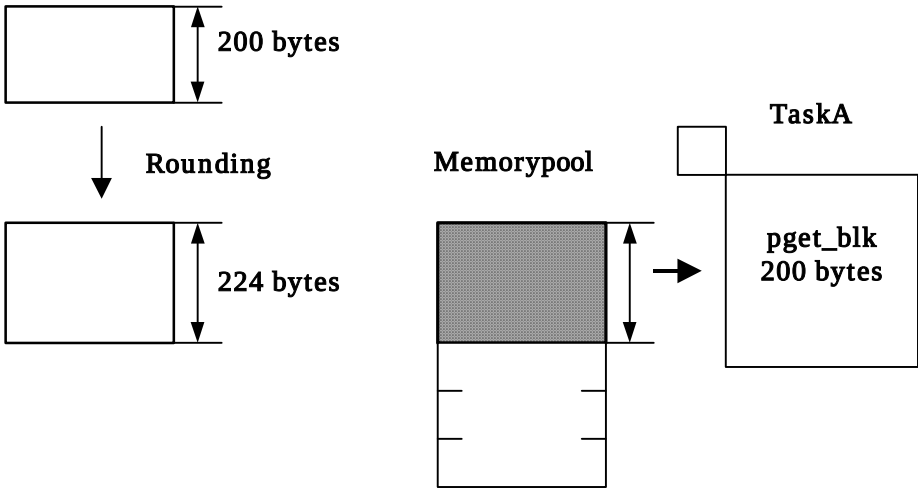


Figure 3.41 pget_blk processing

Figure 3.41 shows an example where task A is requesting 200 bytes of memory block. MR32R rounds off the 200-byte size to 224 bytes, separates a 224-byte memory block off the memorypool, and allocates it to task A.

- Get memory block (pget_blk)
  Acquires a memory block from a variable-size memorypool. The difference with get_blk and tget_blk is that when no memory block of the specified size exists in the memorypool, the issuing task only returns error code without going to a wait state.

- Release memory block (rel_blk)
  Releases the memory block that has been acquired by get_blk, tget_blk, or pget_blk. If there is no task waiting for the memory block of the specified memorypool, the memory block is returned to the memorypool.

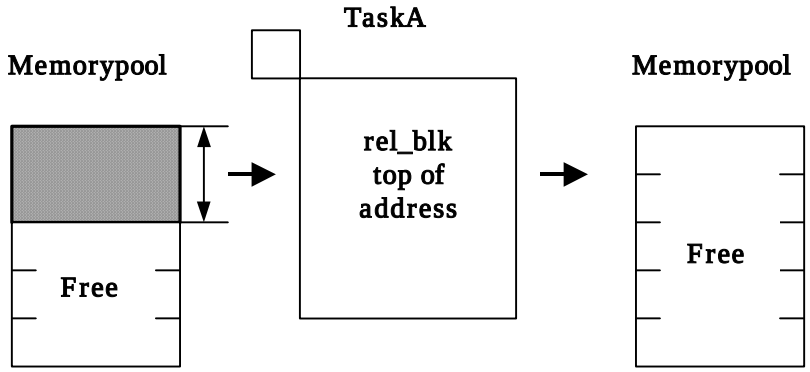


Figure 3.42 rel_blk processing

If when releasing a memory block there is any task waiting for the memory block of the target memorypool, the required size is examined beginning with the first task in the wait queue and when condition is met[39], memory of the required size is separated off the memorypool and allocated to the task, with the task status changed from the wait state to an executable (READY) state. Then the required size of the next task in the queue is compared with the remaining size of the released memory. If the condition is not met for any task in the queue, memory block allocation is finished at that point in time.

[39]It means that the condition is the case the required memory size is lesser than the freed memory size.

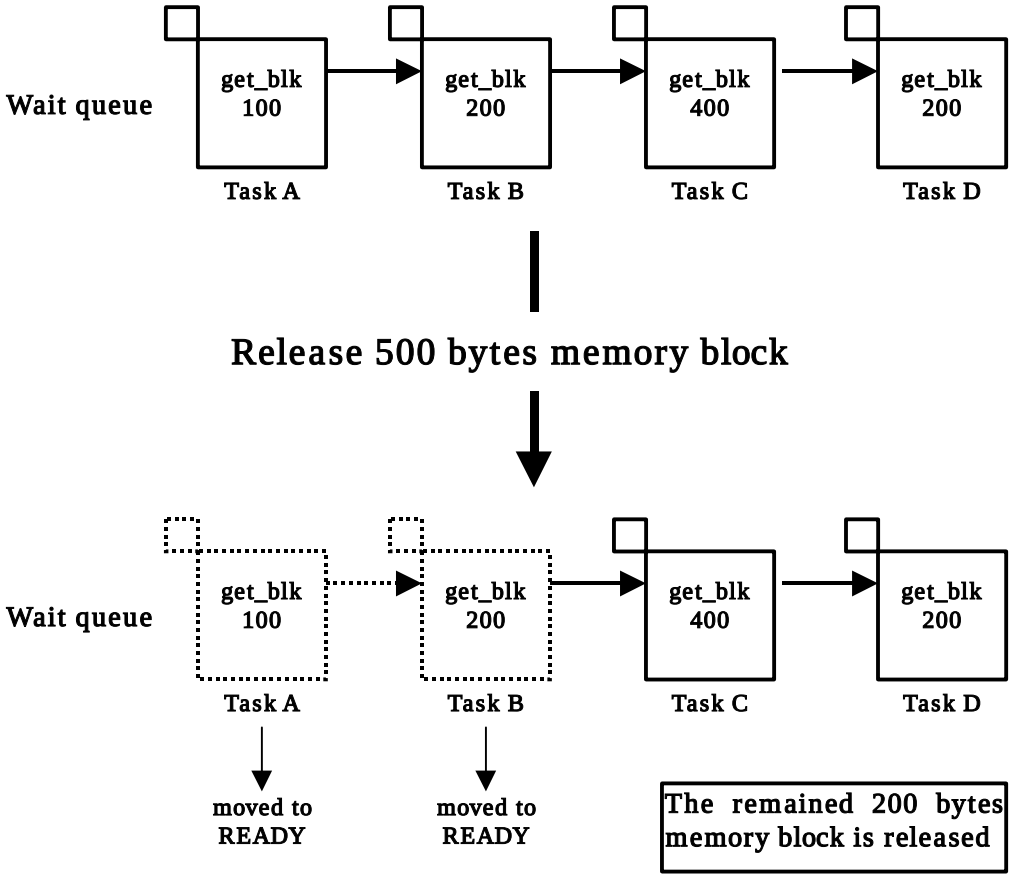


Figure 3.43 Release Memory block

- Referencing the memory pool size (ref_mpl)
  References the aggregate size of blank areas in the memory pool and the maximal blank area size immediately acquirable.

3.5.12 Time Management Function

The time management function provides system time management, time reading[40], time setup[41], and the functions of the alarm handler, which actuates at preselected times, and the cyclic handler, which actuates at preselected time intervals.
The MR32R kernel makes an exclusive use of one M32R Family microcomputer hardware timer as the system timer. The configuration file is used to determine which timer is to be employed as the system timer.
The MR32R kernel offers the following time management system calls.

- Placing a task in wait state for certain time (dly_tsk)
  Keeps a task waiting for a certain time. Figure 3.44shows an example in which task execution is kept waiting for 10 ms by the dly_tsk system call.

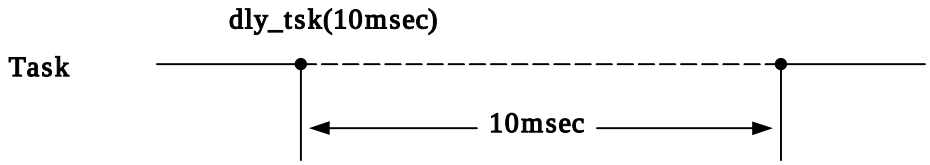


Figure 3.44 dly_tsk system call

You can specify time-out value for the system call below: tslp_tsk,twai_flg,twai_sem,trcv_msg,tsnd_mbf,trcv_mbf,tcal_por,tacp_por,tget_blf,tget_blk.If the time elapses without the wait cancellation condition being satisfied, an error E_TMOUT is returned and the wait state is canceled.If the wait cancellation condition is satisfie, an error E_OK is returned.
A unit of time-out value is the tick of MR32R system clock.

[40] get_tim system call
[41] set_tim system call

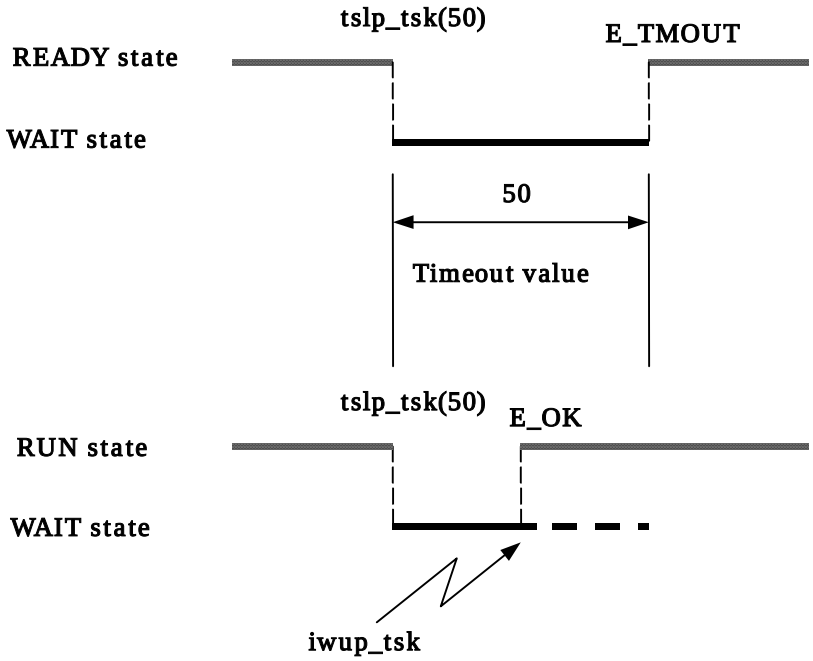


Figure 3.45 Timeout Processing

- Setting the System Time (set_tim)
- Setting the System TimeReading the System Time (get_tim)
  The number of system clock interrupts generated after resetting is counted to indicate the system time in 48-bit data.
- Define a cyclic handler (def_cyc)
  Define a cyclic handlerr.
- Controlling the Cyclic Handler Activity (act_cyc)
  The cyclic handler is a program running at fixed time intervals (See Figure 3.46). It cyclically actuates according to the system clock interrupt count. For cyclic handler control purposes, its activity status is specified by the system call. For example, TCY_ON may be selected to change the activity status from OFF to ON (See Figure 3.47), or TCY_INI_ON may be selected to initialize the handler count (See Figure 3.48).
- Referencing the cyclic handler's status (ref_cyc)
  References the relevant cyclic handler's startup status, and checks the time remaining until the next startup.
- Referencing the alarm handler's status (ref_alm)
  References the time remaining until the relevant alarm handler's startup.

Note that the system timer function is not indispensable.Therefore, if the following system calls and the time management function are not to be used,there is no need to make an exclusive use of one timer for the MR32R.

1. **System clock setup/reading**[42]
2. **Cyclic handler**
3. **Alarm handler**
4. **dly_tsk system call**
5. **The system calls specified time-out value**[43]

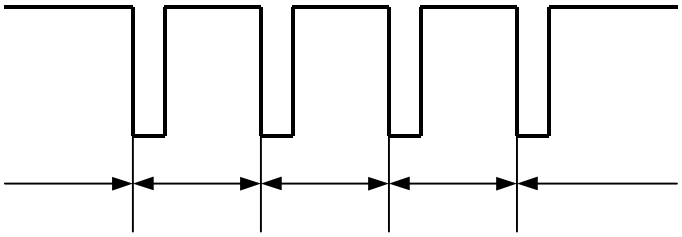


Figure 3.46 Cyclic Handler

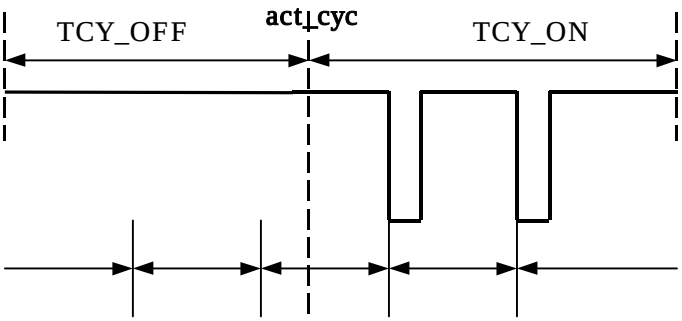


Figure 3.47 Cyclic Handler; TCY_ON Selected as Activity Status

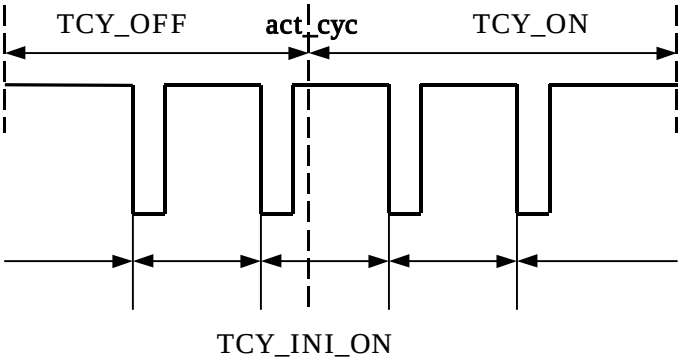


Figure 3.48 Cyclic Handler; TCY_INI_ON Selected as Activity Status

[42] set_tim, get_tim systemcall

[43] tslp_tsk, twai_flg, twai_flg, trcv_msg, tsnd_mbf, trcv_mbf, tcal_por, tacp_por, tget_blf, tget_blk etc.

3.5.13 System Management Function

- Gets information of the MR32R version (get_ver)
  The information on the MR32R version can be obtained using the get_ver system call.
  The version information is obtained in the format standardized in the TRON Specification. The get_ver system call furnishes the following information.

  - **Manufacturer Name**
    Number indicating Mitsubishi Electric Corporation.

  - **Type Number**
    Product identification number.

  - **Specification Version**
    The number representing the μITRON Specification plus the version number of the μITRON Specification document on which the product is based.

  - Product Version
    MR32R version number.

  - **Product Control Information**
    Product release number, release date, and other associated data.

  - **MPU Information**
    Number representing the M32R Family Microcomputer.

  - **Variation Descriptor**
    Number of the function set available for use with the MR32R.

- Refers system status. (ref_sys)
  Refers CPUand OS status as below.
  - System status
    It tells whether the task is running or the handler is running. And whether dispatching is enable or not and whther interrupt is enable or not if the task is running.
  - ID number of the RUN state task.
  - The priority of the RUN state task.
  - PSW value of the RUN state task or the handler

- Defines forced exception handler. (def_exc)
  Defines forced exception handler.The contents of forced exception handler are below.
  - Forced exception attribute
    Specify whether the internal RAM is used for stack or the external RAM is used for stack.
  - Forced exception handler start address
    Specify start address of forced exception handler.
  - The ID number of the task
    Specify the ID number of the task for the forced exception .
  - Stack size
    Specify the stack size used by the forced exception handler.

3.5.14 Implementation-Dependent

Extended function is not specified in µITRON V.3.0 specification,but MR32R support it as its own function.
Exception Management function means that the forced exception handler[44]is defined and executed if an exception[45]is occurred in task processing.
A forced exception handler is defined for each task.Also, all system calls can be issued from task can be issued from forced exception handler.So, If it needs task dispatching, the forced exception handler is dispatched to other task.
MR32R supports the system calls of exception management function as below.

- Starts a forced exception (vras_fex)
  Starts a forced exception handler for the specified ID number of the task.

- Clears a forced exception mask(vclr_ems)
  Clears a forced exception mask for the specified ID number of the task.

- Sets a forced exception mask (vset_ems)
  Sets a forced exception mask for the specified ID number of the task.

- Returns from the forced exception handler to the task.(vret_exc)
  Returns from the forced exception handler to the task.

- Clears a mailbox(vrst_msg)
  Clears a mailbox

- Clears a message buffer(vrst_mbf)
  Clears a message buffer. If there is the send wait state task, its wait state is canceled and an error code EV_RST is returned.

- Resets a fixed-size memory pool (vrst_blf)
  Resets a fixed-size memory pool. If there is the wait state task, its wait state is canceled and an error code EV_RST is returned.

- Resets a variable-size memory pool (vrst_blk)
  Resets a variable-size memory pool. If there is the wait state task, its wait state is canceled and an error code EV_RST is returned.

[44] Forced exception handler only can bedefined. The other exception handler cannot be defined.
[45] When a extraordinary is detected in the whole system.

3.5.15 Implementation-Dependent (Mailbox with Priority)

Mailbox with priority has a message queue for storing the messages which were sent and a message wait queue to which the task waiting any message is connected.

[(Differences to the former bailbox)]

OS kernel manages message queue as link list. You must prepare a header area called as Message-header. This message header and the area used in the application program are called as Message-packet. OS kernel rewrite the message-header to manage mailbox function. You can't modify it.
MR32R defined the message packet data types as below.

T_MSG; message header of the mailbox
T_MSG_PRI; message header for message with priority of the mailbox

The number of the message which is able to be connected to the message queue is not limited because of the application program securing the header area. Also, the task does not become to send wait state. The task can receive the higer priority message from the mailbox by spcifying its attibute as TA_MPRI. The higher priority task can receive the message from the mailbox by spcifying its attibute as TA_TPRI.

- Creates a mailbox with priority.(vcre_mbx)
  Creates a mailbox with priority for the specified ID number of the mailbox.

- Deletes a mailbox with priority.(vdel_mbx)
  Deletes a mailbox with priority for the specified ID number of the mailbox.

- Sends a message(vsnd_mbx, visnd_mbx)
  Sends a message. The task can receive the higer priority message from the mailbox by spcifying its attibute as TA_MPRI.

- Receive a message(vrcv_mbx, vtrcv_mbx, vprcv_mbx)
  Receive a message. The higher priority task can receive the message from the mailbox by spcifying its attibute as TA_TPRI.

- Clears a mailbox(vrst_mbx)
  Clears a mailbox

- Referencing the mailbox's status (vref_mbx)
  Checks whether tasks are present that are waiting for a message to be sent in the relevant mailbox, and references the first message in the mailbox.

3.5.16 System Calls That Can Be Issued from Task and Handler

There are system calls that can be issued from a task and those that can be issued from a handler while there are other system calls that can be issued from both.
Table 3.2 lists those system calls.

Table 3.2List of the system call can be issued from the task and handler

System Call	Task Exception handler	Interrupt handler Cyclic handler Alarm handler
cre_tsk	O	×
del_tsk	O	×
sta_tsk	O	×
ista_tsk	×	O
ext_tsk	O	×
exd_tsk	O	×
ter_tsk	O	×
dis_dsp	O	×
ena_dsp	O	×
chg_pri	O	×
ichg_pri	×	O
rot_rdq	O	×
irot_rdq	×	O
rel_wai	O	×
irel_wai	×	O
get_tid	O	O
ref_tsk	O	O
sus_tsk	O	×
isus_tsk	×	O
rsm_tsk	O	×
irsm_tsk	×	O
slp_tsk	O	×
tslp_tsk	O	×
wup_tsk	O	×
iwup_tsk	×	O
can_wup	O	O
cre_flg	O	×
del_flg	O	×
set_flg	O	×
iset_flg	×	O
clr_flg	O	O
wai_flg	O	×
twai_flg	O	×
pol_flg	O	O
ref_flg	O	O

System Call	Task Exception handler	Interrupt handler Cyclic handler Alarm handler
cre_sem	O	×
del_sem	O	×
sig_sem	O	×
isig_sem	×	O
wai_sem	O	×
twai_sem	O	×
preq_sem	O	O
ref_sem	O	O
cre_mbx	O	×
del_mbx	O	×
snd_msg	O	×
isnd_msg	×	O
rcv_msg	O	×
trcv_msg	O	×
prcv_msg	O	O
ref_mbx	O	O
cre_mbf	O	×
del_mbf	O	×
snd_mbf	O	×
tsnd_mbf	O	×
psnd_mbf	O	×
rcv_mbf	O	×
trcv_mbf	O	×
prcv_mbf	O	×
ref_mbf	O	O
cre_por	O	×
del_por	O	×
cal_por	O	×
tcal_por	O	×
pcal_por	O	×
acp_por	O	×
tacp_por	O	×
pacp_por	O	×
fwd_por	O	×
rpl_rdv	O	×
ref_por	O	O

System Call	Task Exception handler	Interrupt handler Cyclic handler Alarm handler
def_int	O	×
ret_int	×	O[46]
loc_cpu	O	×
unl_cpu	O	×
cre_mpf	O	×
del_mpf	O	×
get_blf	O	×
tget_blf	O	×
pget_blf	O	O
rel_blf	O	×
ref_mpf	O	O
cre_mpl	O	×
del_mpl	O	×
get_blk	O	×
tget_blk	O	×
pget_blk	O	×
rel_blk	O	×
ref_mpl	O	O
set_tim	O	O
get_tim	O	O
dly_tsk	O	×
act_cyc	O	O
ref_cyc	O	O
ref_alm	O	O
get_ver	O	O
ref_sys	O	O
def_exc	O	×
vclr_ems	O	×
vset_ems	O	×
vret_exc	O	×
vras_fex	O	×
def_cyc	O	×

*:vret_exc can’t be issued from a task.

[46] The System Call can't be issued from the Interrupt Handler in C language.

System Call	Task Exception handler	Interrupt handler Cyclic handler Alarm handler
vrst_msg	O	×
vrst_mbf	O	×
vrst_blf	O	×
vrst_blk	O	×
vcre_mbx	O	×
vdel_mbx	O	×
vsnd_mbx	O	×
visnd_mbx	×	O
vrcv_mbx	O	×
vtrcv_mbx	O	×
vprcv_mbx	O	O
vrst_mbx	O	×
vref_mbx	O	O

Chapter 4 Applications Development Procedure Overview

4.1 General Description

The MR32R application programs are generally developed using the following procedures.

1. **Applications Program Coding**
   Code an applications program in C or assembly language.
2. **Generating an interrupt control program**
   Generate an interrupt control program "ipl.ms"(for CC32R) and "ipl.s"(for TW32R, DCC/M32R)involved in the board M3A-2131 for the evaluation of M32102, which is appended to the product.
3. **Configuration File Preparation**
   Using the editor, prepare the configuration file in which the task entry address, stack size, and the like are defined.
4. **Configurator Execution**
   Using the configuration file, create the system data definition files (sys_rom.inc and sys_ram.inc), include files (mr32r.inc and id.h), and system generation procedure description file (makefile).
5. **System Generation**
   Generate the system by executing the make[47] command.
6. **Writing into ROM**
   Using the prepared ROM write form file, write the program into ROM, or allow the debugger to read the program to conduct debugging.

Figure 4.1 shows MR32R System Generation Detail Flowchart.

[47] The make command comes the UNIX standard and UNIX compatible.

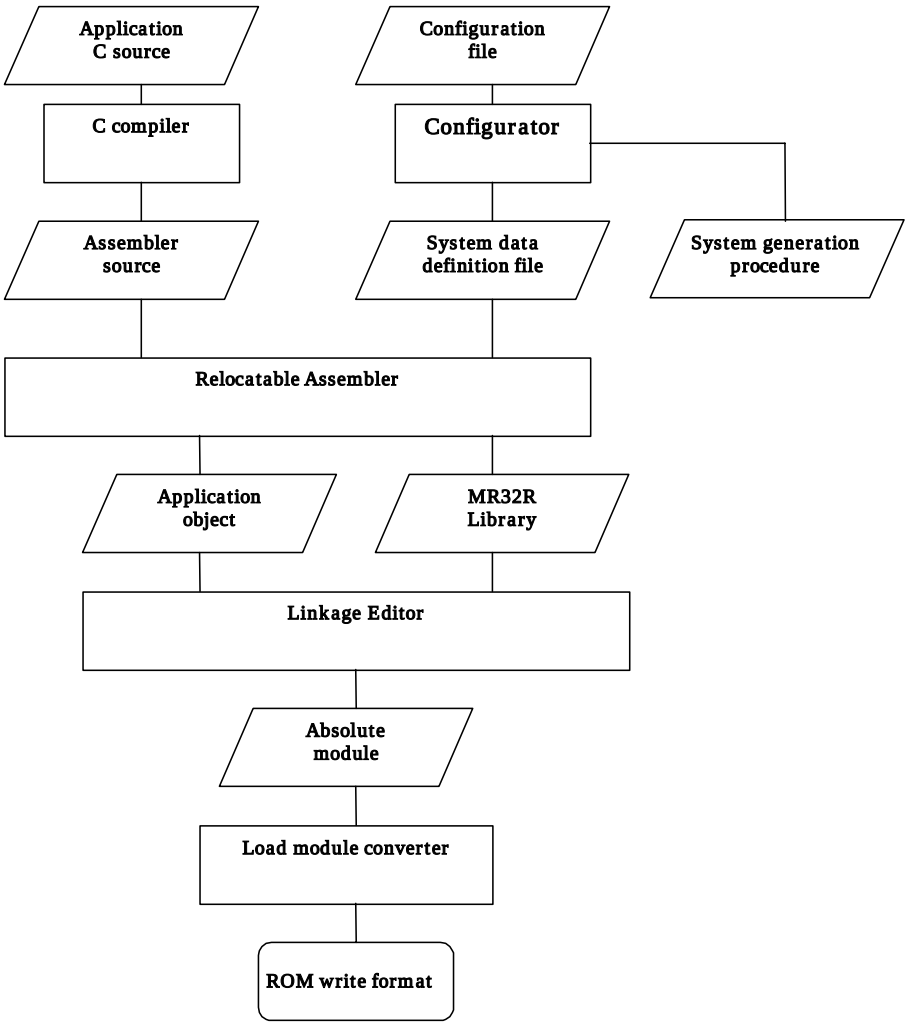


Figure 4.1 MR32R System Generation Detail Flowchart

4.2 Development Procedure Example

This chapter outlines the development procedures on the basis of a typical MR32R application example.

4.2.1 Applications Program Coding

Figure 4.2 shows a program that simulates laser beam printer operations. Let us assume that the file describing the laser beam printer simulation program is named lbp.c. This program consists of the following three tasks and one interrupt handler.

- Main Task
- Image expansion task
- Printer engine task
- Centronics interface interrupt handler

This program uses the following MR32R library functions.

- sta_tsk()
  Starts a task. Give the appropriate ID number as the argument to select the task to be activated. When the id.h file, which is generated by the configurator, is included, it is possible to specify the task by name (character string).[48]
- wai_flg()
  Waits until the eventflag is set up. In the example, this function is used to wait until one page of data is entered into the buffer via the Centronics interface.
- wup_tsk()
  Wakes up a specified task from the WAIT state. This function is used to start the printer engine task.
- slp_tsk()
  Causes a task in the RUN state to enter the WAIT state. In the example, this function is used to make the printer engine task wait for image expansion.
- iset_flg()
  Sets up the eventflag. In the example, this function is used to notify the image expansion task of the completion of one-page data input.

[48] The configurator converts the ID number to the associated name(character string) in accordance with the information entered int the configuration file.

```
#include <mr32r.h>
#include "id.h"


void main() /* main task */
{
    printf("LBP start simulation ¥n");
    sta_tsk(ID_idle,1);     /* activate idle task */
    sta_tsk(ID_image,1);    /* activate image expansion task */
    sta_tsk(ID_printer,1);  /* activate printer engine task */
}
void image() /* activate image expansion task */
{
    while(1){
            wai_flg(&flgptn,ID_pagein,waiptn,TWF_ANDW+TWF_CLR);/* wait for 1-
page input */

            printf(" bit map expansion processing ¥n");
            wup_tsk(ID_printer);    /* wake up printer engine task */
    }
}
void printer() /* printer engine task */
{
    while(1){
            slp_tsk();
            printf(" printer engine operation ¥n");
    }
}
void sent_in() /* Centronics interface handler */
{


    /* Process input from Centronics interface */
    if ( /* 1-page input completed */ )
            iset_flg(ID_pagein,setptn);
}
```

Figure 4.2 Program Example

4.2.2 Configuration File Preparation

Prepare the configuration file in which the task entry address, stack size, and the like are defined.

```
// System Definition
 system{
    stack_size              = 1024;
    priority                = 5;
};
 //System Clock Definition
 clock{
    timer_clock             = 33.3MHz;
    timer                   = MFT00;
    file_name               = m32102.tpl;
    IPL                     = 4;
    unit_time               = 10ms;
    initial_time            = 0:0:0;
 };
 //Task Definition
 task[1]{
    entry_address           = main();
    stack_size              = 512;
    priority                = 1;
    initial_start           = ON;
 };
 task[2]{
    entry_address           = image();
    stack_size              = 512;
    priority                = 2;
 };
 task[3]{
    entry_address           = printer();
    stack_size              = 512;
    priority                = 4;
 };
 task[4]{
    entry_address           = idle();
    stack_size              = 256;
    priority                = 5;
 };
 //Eventflag Definition
 flag[1]{
     name                   = pagein;
 };
 //Interrupt Vector Definition
interrupt_vector[16]              = __sys_timer;
interrupt_vector[23]              = sent_in();
```

Figure 4.3 shows the configuration file (named "lbp.cfg") of the laser beam printer simulation program.

```
// System Definition
 system{
    stack_size              = 1024;
    priority                = 5;
};
 //System Clock Definition
 clock{
    timer_clock             = 33.3MHz;
    timer                   = MFT00;
    file_name               = m32102.tpl;
    IPL                     = 4;
    unit_time               = 10ms;
    initial_time            = 0:0:0;
 };
 //Task Definition
 task[1]{
    entry_address           = main();
    stack_size              = 512;
    priority                = 1;
    initial_start           = ON;
 };
 task[2]{
    entry_address           = image();
    stack_size              = 512;
    priority                = 2;
 };
 task[3]{
    entry_address           = printer();
    stack_size              = 512;
    priority                = 4;
 };
 task[4]{
    entry_address           = idle();
    stack_size              = 256;
    priority                = 5;
 };
 //Eventflag Definition
 flag[1]{
     name                   = pagein;
 };
 //Interrupt Vector Definition
interrupt_vector[16]              = __sys_timer;
interrupt_vector[23]              = sent_in();
```

Figure 4.3 Configuration File Example

4.2.3 Configurator Execution

Execute the configurator cfg32r to generate the system data definition files (sys_rom.inc and sys_ram.inc), include files (mr32r.inc and id.h), and system generation procedure description file (makefile) from the configuration file.

```
A> cfg32r  -mv  lbp.cfg
MR32R system configurator V.3.40.00 (for CC32R)
Copyright 1998-2000 MITSUBISHI ELECTRIC CORPORATION,
and MITSUBISHI ELECTRIC SEMICONDUCTOR APPLICATION ENGINEERING CORPORATION
All Rights Reserved
MR32R version ==> V.3.40 Release 1
A>
```

Figure 4.4 Configurator Execution

4.2.4 System generation

Execute the make command [49] to generate the system.

```
C> make -f  makefile
 as32R -g crt0mr.ms
 cc32R -c task.c
 lnk32R lnk32R.sub

 C>
```

Figure 4.5 System Generation

4.2.5 Writing ROM

Using the LMC32R (for CC32R) or m32r-elf-objcopy (for TW32R) load module converter, convert the absolute module file into a ROM writable format and then write it into ROM. Or read the file into the debugger and debug it.

[49] It is possible for MR32R to use only "make" command compatible to UNIX standard. To use MS-DOS, use "make" command(for instance, "nmake" command attached to C-compiler make by Microsoft Corporation compatible to UNIX. For "make" command interchangeable to UNIX, refer to the release note. This paragraph describes an example for case when "nmake" command interchangeable to UNIX is executed.

Chapter 5 Detailed Applications

5.1 Program Coding Procedure in C Language

This chapter details the applications program development procedures in C language.

5.1.1 Task Description Procedure

Note the items as below when a task written in C language.

1. **Describe the task as a function.**
   To register the task for the MR32R, enter its function name in the configuration file. When, for instance, the function name "task()" is to be registered as the task ID number 3, proceed as follows.

```
task[3]{
        entry_address   = task();
        stack_size      = 100;
        priority        = 3;
};
```

2. **At the beginning of file, be sure to include "mr32r.h" which is in system directory as well as "id.h" which is in the current directory. That is, be sure to enter the following two lines at the beginning of file.**

```
#include <mr32r.h>
#include "id.h"
```

3. **No return value is provided for the task start function. Therefore, declare the task start function as a void function.**
4. **A function that is declared to be static cannot be registered as a task.**
5. **It is necessary to describe ext_tsk at the exit of task start function.**
6. **It is also possible to describe the task startup function, using the infinite loop.**

```
#include <mr32r.h>
#include "id.h"
void task(void)
{
        /* process */
}
```

Figure 5.1 Example Infinite Loop Task Described in C Language

```
#include <mr32r.h>

#include "id.h"

void task(void)
{
        for(;;){
                /* process */

        }
}
```

Figure 5.2 Example Task Terminating with ext_tsk() Described in C Language

7. When designating a task, use a character string consisting of "ID_" and task function name.[50]

```
wup_tsk(ID_main);
```

8. When designating an eventflag, semaphore, mailbox, or memorypool, use a character string consisting of "ID_" and the name defined in the configuration file.

Suppose that the eventflag is defined as follows in the configuration file.

```
flag[1]{
        name    = abc;
};
```

To designate this eventflag, proceed as follows.

```
set_flg(ID_abc,&setptn);
```

9. When designating the cyclic handler or alarm handler, use a character string consisting of "ID_" and handler start function name. To designate the cyclic handler "cyc()," for instance, proceed as follows.

```
act_cyc(ID_cyc,TCY_ON);
```

10. When a task is reactivated by the sta_tsk() system call after it has been terminated by the ter_tsk() system call, the task itself starts from its initial state.[51] However, the external variable and static variable are not automatically initialized when the task is started. The external and static variables are initialized only by the startup program, which actuates before MR32R startup.

11. The task executed when the MR32R system starts up is setup.

12. The variable storage classification is described below.

The MR32R treats the C language variables as indicated in Table 5.1.

[50] The configurator generates the "id.h" file which converts the task ID number to the associated character string for task designation. That is, "id.h" is used to make the #define declaration for converting the character string consisting of "ID_" and task start function name to the task ID number.

[51] Started beginning with the task start function at the initial priority level and with the wake-up count cleared.

Table 5.1C Language Variable Treatment

Variable storage class	Treatment
Global Variable	Variable shared by all tasks
Non-function static variable	Variable shared by the tasks in the same file
Auto Variable Register Variable Static variable in function	Variable for specific task

5.1.2 Writing Interrupt Handler

When describing the interrupt handler in C language, observe the following precautions.

1. **Describe the interrupt handler as a function** [52]
2. **Be sure to use the void type to declare the interrupt handler start function return value and argument.**
3. **At the beginning of file, be sure to include "mr32r.h" which is in the system directory as well as "id.h" which is in the current directory.**
4. **The static declared functions can not be registered as an interrupt handler.**

```
#include <mr32r.h>

#include "id.h"

void int_handler(void)

{
        /* process */

        iwup_tsk(ID_main);
}
```

Figure 5.3 Example of Interrupt Handler

[52] A configuration file is used to define the relationship between handlers and functions.

5.1.3 Writing Cyclic Handler/Alarm Handler

When describing the cyclic or alarm handler in C language, observe the following precautions.

1. **Describe the cyclic or alarm handler as a function.[53]**
2. **Be sure to declare the return value and argument of the interrupt handler start function as a void type.**
3. **At the beginning of file, be sure to include "mr32r.h" which is in the system directory as well as "id.h" which is in the current directory.**
4. **The static declared functions cannot be registered as a cyclic handler or alarm handler.**
5. **The cyclic handler and alarm handler are invoked by a subroutine call from a system clock interrupt handler.**

```
#include <mr32r.h>

#include "id.h"

void cychand(void)
{
        /* process */
}
```

Figure 5.4 Example Cyclic Handler Written in C Language

[53] The handler-to-function name correlation is determined by the configuration file.

5.1.4 Writing Exception (forced exception) handler.

When writing exception handlers in C language, pay attention to the following:

1. **Write the exception handler as a function.**
2. **Declare the return value of the function using the void type.**
3. **For the function argument, specify the pointer to the exception information packet (T_EXC *pk_exc), the pointer to the register information packet to be referenced when an exception occurs (T_REGS *pk_regs), or the pointer to the EIT information packet (T_EIT *pk_eit).**
4. **At the beginning of the file, always be sure to include "mr32r.h" that is stored in the system directory and "id.h" that is stored in the current directory.**
5. **The functions that have been static declared cannot be registered as an exception handler.**
6. **Use the vret_exc system call to terminate the handler.[54]**
   When the vret_exc system call is issued, processing is transferred to the task for which the exception handler was called.

```
#include <mr32r.h>
#include "id.h"
T_EXC exc;
T_REGS regs;
T_EIT eit;

/* Prototype declaration */
void exc_handler(T_EXC *, T_REGS *, T_EIT *);

void exc_handler(T_EXC &exc, T_REGS &regs, T_EIT &eit)
{

            /* process */

            vret_exc();

}
```

Figure 5.5 Example Exception Handler Written in C Language

[54] ext_tsk system call can be issued when forced exception handler ends. In this case,the task corresponding to the forced exception handler is moved to DORMANT state.

5.2 Program Coding Procedure in Assembly Language

This section describes how to write an application using the assembly language.

5.2.1 Writing Task

This section describes how to write an application using the assembly language.

1. **Be sure to include "mr32r.inc" at the beginning of file.**
2. **For the symbol indicating the task start address, make the external declaration.[55]**
3. **Be sure that an infinite loop is formed for the task or the task is terminated by the ext_tsk system call.**

```
        .include  “mr32r.inc”----- (1)
        .global    task    ----- (2)

task:
                ; process
        bra   task      ----- (3)
```

Figure 5.6 Example Infinite Loop Task Described in Assembly Language

```
        .include  “mr32r.inc”
        .global   task

task:
                ; process
        ext_tsk
```

Figure 5.7 Example Task Terminating with ext_tsk Described in Assembly Language

4. **The initial register values except PC, PSW and following registers are indeterminate.**

   - For M32R Family Cross Tool **CC32R**
     A start code is stored R2 and R4 register.
   - For M32R Family Cross Tool **TW32R,D-CC/M32R**
     A start code is stored R0 and R2 register.

5. **When designating a task, use a character string consisting of “ID_” and task function name.[56]**

```
        wup_tsk  ID_task
```

6. **When specifying an eventflag, semaphore, or mailbox, use a character string that consists of the name defined in the configuration file plus "ID_" as you specify it.**
   For example, assume that the semaphore is defined in the configuration file as follows:

```
semaphore[1]{
        name            = abc;
};
```

   To specify this semaphore, write your specification as follows:

[55] Use the .GLOBAL pseudo-directive
[56] The configurator generates pseudo-directive. to convert from the strings to the ID No. of the task in “mr32r.inc” file.

```
sig_sem  ID_abc
```

7. When specifying a cyclic handler or alarm handler, use a character string that consists of the handler's start symbol name plus "ID_" as you specify it.

For example, if you want to specify a cyclic handler "cyc," write your specification as follows:

```
act_cyc  ID_cyc,TCY_ON
```

8. Set a task that is activated at MR32R system startup in the configuration file [57]

[57] The relationship between task ID numbers and tasks(program) is defined in the configuration file.

5.2.2 Writing Interrupt Handler

When describing the OS-dependent interrupt handler in assembly language, observe the following precautions

1. **At the beginning of file, be sure to include "mr32r.inc" which is in the system directory.**
2. **For the symbol indicating the interrupt handler start address, make the external declaration(Global declaration).[58]**
3. **Make sure that the registers used in a handler are saved at the entry and are restored after use.**
4. **Return to the task by ret_int system call.**

```
                .include  “mr32r.inc”          ------(1)
                .global   inth                 ------(2)

        inth:
                ;  Registers used are saved on a stack   ------(3)
                iwup_tsk  ID_task1
                        :
                        process
                        :

                ;  Registers used are restored  ------(3)

                ret_int                        ------(4)
```

Figure 5.8 Example of interrupt handler

[58] Use the .GLOBAL pseudo-directive.

5.2.3 Writing Cyclic Handler/Alarm Handler

When describing the cyclic or alarm handler in Assembly Language, observe the following precautions.

1. **At the beginning of file, be sure to include "mr32r.inc" which is in the system directory.**
2. **For the symbol indicating the handler start address, make the external declaration.[59]**
3. **Always use the jmp instruction to return from cyclic handlers and alarm handlers.**
   For examples:

```
.include        “mr32r.inc”     ----- (1)
.global         cychand         ----- (2)

cychand:
        st      R14,@-R15
                :
        ; handler process
                :
        ld      R14,@R15+

        jmp     R14             ----- (3)
```

Figure 5.9 Example Cyclic Handler Written in Assembly Language

[59] Use the .GLOBAL pseudo-directive.

5.2.4 Writing Exception (forced exception) handler.

When writing exception handlers in the assembly language, pay attention to the following:

1. **At the beginning of file, be sure to include "mr32r.inc" which is in the system directory.**
2. **For the symbol indicating the handler start address, make the external declaration.**
3. **Use the vret_exc system call to terminate the handler.[60]**
   When the vret_exc system call is issued, processing is transferred to the task for which the exception handler was called.

   The parameters passed to the exception handler at invocation have been set in the following registers:

Register Name	Value
R0	T_EXC *pk_exc
R1	T_REGS *pk_regs
R2	T_EIT *pk_eit

```
.include        mr32r.inc       ----- (1)
.global         exc_handler     ----- (2)

exc_handler:

                :
        ; handler process
                :


        vret_exc                        ----- (3)
```

Figure 5.10 Example exception handler Written in Assembly Language

[60] ext_tsk system call can be issued when forced exception handler ends. In this case,the task corresponding to the forced exception handler is moved to DORMANT state.

Chapter 6 Notes of developing user program

6.1 MR32R has four system calls related to delay dispatching.

- dis_dsp
- ena_dsp
- loc_cpu
- unl_cpu

The following describes task handling when dispatch is temporarily delayed by using these system calls.

1. When the execution task in delayed dispatch is preempted

While dispatch is disabled, even under conditions where the task under execution should be preempted, no time is dispatched to new tasks that are in an executable state. Dispatching to the tasks to be executed is delayed until the dispatch disabled state is cleared. When dispatch is being delayed

- Task under execution is in a RUN state and is linked to the ready queue
- Task to be executed after the dispatch disabled state is cleared is in a READY state and is linked to the highest priority ready queue (among the queued tasks).

2. isus_tsk, irsm_tsk during delayed dispatch

In cases when isus_tsk is issued from an interrupt handler that has been invoked in a dispatch disabled state to the task under execution (a task to which dis_dsp was issued) to place it in a SUSPEND state. During delayed dispatch.

- The task under execution is handled inside the OS as having had its delayed dispatch cleared. For this reason, in isus_tsk that has been issued to the task under execution, the task is removed from the ready queue and placed in a SUSPEND state. Error code E_OK is returned. Then, when irms_tsk is issued to the task under execution, the task is linked to the ready queue and error code E_OK is returned. However, tasks are not switched over until delayed dispatch is cleared.
- The task to be executed after delayed disabled dispatch is re-enabled is linked to the ready queue.

3. rot_rdq, irot_rdq during delayed dispatch

When rot_rdq (TPRI_RUN = 0) is issued during delayed dispatch, the ready queue of the own task's priority is rotated. Also, when irot_rdq (TPRI_RUN = 0) is issued, the ready queue of the executed task's priority is rotated. In this case, the task under execution may not always be linked to the ready queue. (Such as when isus_tsk is issued to the executed task during delayed dispatch.)

4. Precautions

- No system call (e.g., slp_tsk, wai_sem) can be issued that may place the own task in a wait state while in a state where dispatch is disabled by dis_dsp or loc_cpu.
- ena_dsp and dis_dsp cannot be issued while in a state where interrupts and dispatch are disabled by loc_cpu.
- Disabled dispatch is re-enabled by issuing ena_dsp once after issuing dis_dsp several times.

The above status transition can be summarized in the table below.

Table 6.1Interrupt and Dispatch Status Transition by dis_dsp and loc_cpu

Status No.	Contents of Statusdis		dis_dsp is executed	ena_dsp is executed	loc_cpu is executed	unl_cpu is executed
	Interrupt	Dispatch				
1	Enabled	Enabled	→ 2	→ 1	→ 3	→ 1
2	Enabled	Disabled	→ 2	→ 1	→ 3	→ 1
3	Disabled	Disabled	×	×	→ 3	→ 1

6.2 Regarding Initially Activated Task

MR32R allows you to specify a task that starts from a READY state at system startup. This specification is made by setting the configuration file.
Refer to page 132 for details on how to set.

6.3 A note on using alarm handler

Keep in mind that they are the following specifications at the time of alarm handler use in MR32R.

- The alarm handler started at once is not again started, though set up the system time by the set_tim system call before starting time.
- When time is set up after the starting time of the alarm handler which has not been started yet by the set_tim system call, the alarm handler after setting time does not start. Please let start sequentially from the early alarm handler of starting time, and be sure to make.

6.4 About dynamic generation and deletion of the objects

6.4.1 Structure of Memory in Dynamic Allocation Generation / Deletion

In case dynamic generation functions (cre_tsk, cre_mpf, cre_mpl, etc.) are used, it is made to assign the optimal size among the memory blocks of four sizes like the variable size memory pool function in MR32R. the target system call is boiled and shown below.

Table 6.2 Dynamic generation / deletion system call list

System Call	Function
cre_tsk,del_tsk,exd_tsk	for stack area
def_exc	for stack area of the exception
cre_mbx,del_mbx	for mailbox area
cre_mbf,del_mbf	for messagebuffer are
cre_mpf,del_mpf	for fixed-size memorypool are
cre_mpl,del_mpl	for variable size memorypool area

The size (a, b, c, d) of four memory blocks as well as the variable size memory pool is calculable as follows. Since the following sizes include management information, they become a value fewer 12 bytes than this in fact.

a =(((max_memsize +(12-1))/96)+1)*12
b =a*2
c =a*4
d =a*8

[Example]

The task is generated with "__MR_EXT__" attribute in the user program.
Task A : 256 bytes of stack
Task B : 1024 bytes of stack

In this case, since the stack size of Task B serves as the maximum, more than max_memsize = 1024 is specified. When the ext_memstk definition of a configuration file is set to max_memsize = 1024, the size of four memory blocks is as follows from the above-mentioned formula.

kind of memory	size	Size which can be real used
a	132	120
b	264	252
c	528	516
d	1056	1040

- 12 bytes of difference are used as a management information.

Since the stack size of Task A is 256 bytes, the block of size c (=528) is assigned. therefore the stack size (1024 bytes) of Task B is allocated d (=1056) byte memory block.
The relation of demand size, real use size, and useless size is as follows.

	demand size	real use size	useless size
TaskA	256	528	272
TaskB	1024	1056	32
Total	1280	1584	304

Therefore, if it describes as follows to a configuration file, it will not become the shortage of a memory.

Description of a configuration file

```
ext_memstk{
      max_memsize     = 1024;
      all_memsize     = 1584;
};
```

However, if it describes in this way, 304 bytes of useless memory area will be made. In order to reduce a useless memory area, it is necessary to adjust max_memsize.
For example, it is set to max_memsize=1048, then a=144 b=288 c=576 d=1152.

	demand size	real use size	useless size
TaskA	256	288	32
TaskB	1024	1152	128
Total	1280	1440	160

If it does in this way, it is possible to reduce useless size.

6.4.2 A note on using dynamic generation / deletion

(1) By this system, fragmentation may be generated, although it has been hard coming to generate. Therefore, keep in mind that a memory block may not be allocated although there is size of enough of an empty memory area.
(2) A part for the memory size which specified the variable size memory pool generated by cre_mpl system call at the time of generation is not necessarily used. A part for the size of the memory block which OS allocated is used as a memory pool area. Therefore, when the value specified as memory pool size by the configuration file is made into the argument of cre_mpl, the memory pool size for which those who used cre_mpl are actually used may become large.

6.5 The Use of TRAP Instruction

MR32R has TRAP instruction interrupt numbers reserved for issuing system calls as listed in Table 6.3. For this reason, when using software interrupts in a user application, do not use interrupt numbers 7 and 8, and be sure to use some other numbers.

Table 6.3Interrupt Number Assignment

TRAP No.	System calls Used
7	System calls that can be issued from only task
8	System calls that can ce issued from only handlers System calls that can be issued from both tasks and handlers
9 ~12	Reserved for future extension

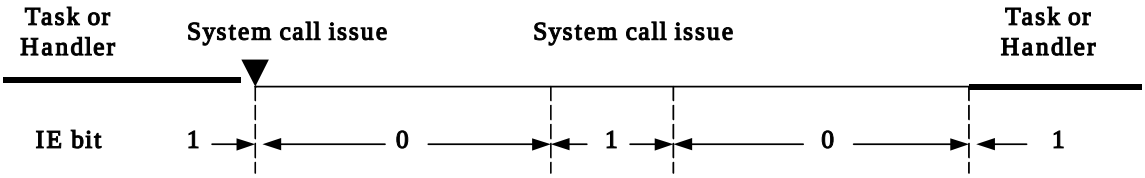
6.6 Regarding Interrupts

6.6.1 Controlling Interrupts

To enable or disable interrupts within a system call, you manipulate the PSW's IE bit.
The IE bit within a system call has been cleared to disable interrupts. Interrupts caused by the interrupt hander have been disabled. In a situation in which every interrupt can be enabled, the IE bit is returned to the status as it was when a system call was issued.
Here follows the status of the interrupt enabling flag within a system call.

- For system calls that can be issued from only task

- **When the IE flag before issuing a system call is 0**



- **When the IE flag before issuing a system call is 1**

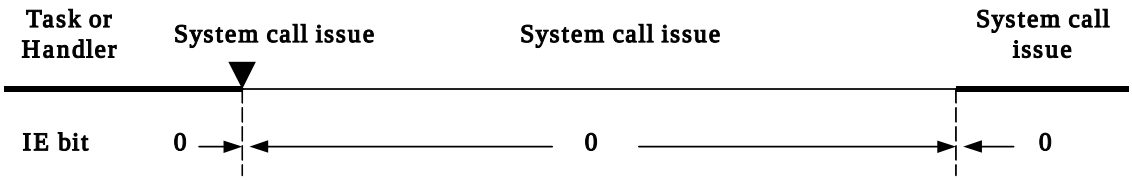


Figure 6.1 Interrupt control in a System Call that can be Issued

As shown in Figure 6.1 , the interrupt enabling flag varies in value within a system call. Thus it is not recommended to manipulate the interrupt disabling flag so as to disable interrupts within a user application. The following two methods for interrupt control are recommended:

1. **Modify the interrupt control register for the interrupt you want to be disabled.**
2. **Use system calls loc_cpu and unl_cpu.**

6.6.2 The procedure for running the interrupt handler

MR32R runs the interrupt handler in line with the procedure as shown in Figure 6.2.

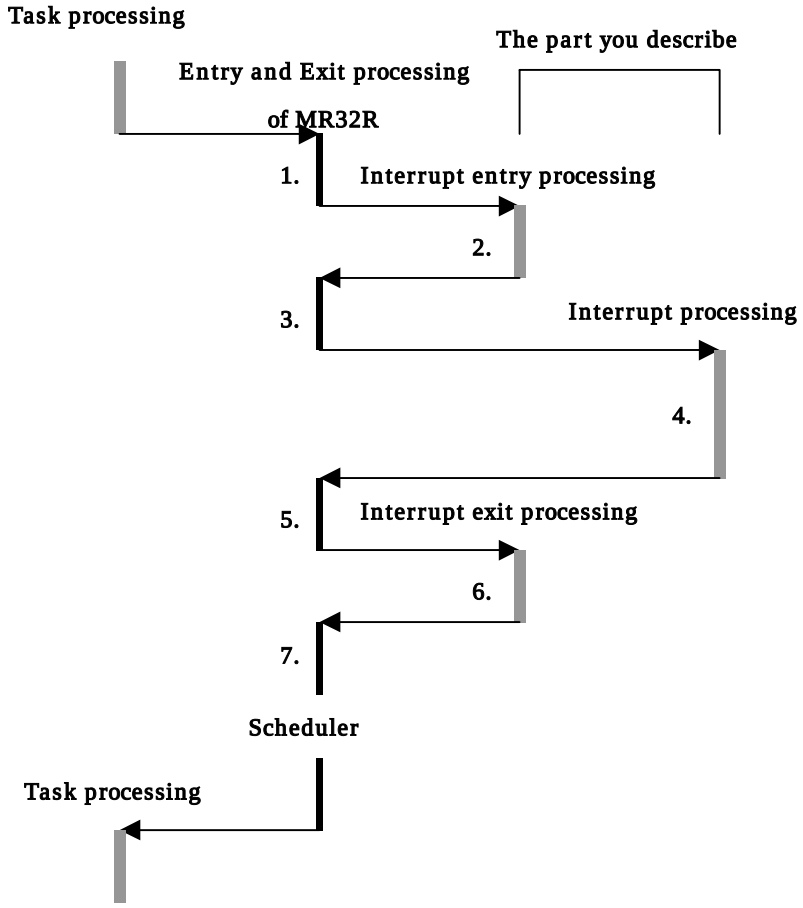


Figure 6.2 The procedure for running the interrupt handler

1. **Stores the register, and calls the user's interrupt entry processing routine.**
2. **The user's interrupt entry processing routine**
   - Reads the interrupt level, and saves it in the stack.
   - Reads the interrupt factor, and piles the jump address of the interrupt on the stack.
3. **Calls the address of the interrupt handler piled on the stack.**
4. **The interrupt handling routine**
5. **Calls the user's interrupt exit routine.**
6. **The interrupt exit routine**
   - Restores the interrupt level to the former state.
7. **Restores the interrupt level to the former state.**

Steps 2 and 6 need to be written within the interrupt control program (ipl.ms) by the user (for details, see Section 8.1); others are processed by the OS.

6.6.3 Acception of Interruption at Time of Handler Execution

- Alarm Handler and Cyclic Handler
  The cyclic handler and alarm handler are started in the state of interruption permission.

- Interrupt Handler
  By the default, an interrupt handler is started in the state of interruption prohibition.

6.6.4 Enabling Multiple Interrupts

To enable multiple interrupts, follow the steps given below.

- To enable multiple interrupts for any interrupts

  1. **Set the interrupt enabling bit within the interrupt entry processing routine Step 2 above.**

  2. **Clear the interrupt enabling bit within the interrupt exit processing routing Step 1 above.**

- To enable multiple interrupts for specific interrupts

  1. **Set the interrupt enabling bit at the beginning of the interrupt handler that enables multiple interrupts.**

  2. **Clear the interrupt enabling bit at the tail of the interrupt handler that enables multiple interrupts.**

6.7 The procedure of using OS debug functions

The following things are the procedure of using OS debug functions (e.q. task trace function,system call trace function and issuing system call function.) and the precautions about it.

6.7.1 The procedure of using OS debug functions

1. Modify the item of system definition in configuration file.
   Details are discribed in 6.1 Configuration File Creation Procedure.
2. Link your program with the library of the hook routine “mrdbg.lib”(for CC32R) or “libmrdbg.a”(for TW32R ,D-CC/M32R)
3. Map the hook routine section(OS_DEBUG) and the buffer area for OS debugging section(MR_dbg_RAM) to any address.
4. Specify “YES” keyword in the system call definition item of the configuration file when using issuing system call function.
5. Modify from “__sys_timer” to “Dbg_sys_timer” in the interrupt handler definitionof the configuration file.
   (__Dbg_sys_timer is the hook routine for issuing system call function.)

6.7.2 Precautions in using OS debug functions

- Please set the system clock interval in 10ms.Because the debugger cannot display the time line of MR trace window correctly when the system clock interval is over 10 ms. (but it display the factor and order of task switching correctly.)
- You cannot use task trace function,system call trace function and issuing system call function when the debugger does not support these function.
- The system calls issued from interrupt handler can use in issuing system call function except “get_tid” system call. The system calls issued from task cannot be used.
- The processing time and interrupt disable time are longer when using OS debug functions.
- To control the task trace function and system call trace function, MR32R communicate the debugger via a byte of data “__Dbg_mode”. The default start-up routine disables task trace function and system call trace function. So, if the program is downloaded into target board and open MR trace window, the debugger does not display the trace result. Please open MR trace window after start-up routine executed.
  The following is the procedure of enabling task trace function and system call trace function in start-up routine for CC32R.

[Modified]

```
;       seth    R11,#high(__REL_BASE11)
;       or3     R11,R11,#low(__REL_BASE11)
;       seth    R12,#high(__REL_BASE12)
;       or3     R12,R12,#low(__REL_BASE12)
;       seth    R13,#high(__REL_BASE13)
;       or3     R13,R13,#low(__REL_BASE13)


.AIF    ¥&__Dbg_flg gt 0
ld24    r1,#__Dbg_mode
ldi     r2,#0           <-Set the value to R2 register
stb     r2,@r1             This example sets “AFTER” mode
.AENDI
```

[Original]

```
;       seth    R11,#high(__REL_BASE11)
;       or3     R11,R11,#low(__REL_BASE11)
;       seth    R12,#high(__REL_BASE12)
;       or3     R12,R12,#low(__REL_BASE12)
;       seth    R13,#high(__REL_BASE13)
;       or3     R13,R13,#low(__REL_BASE13)


        .AIF    ¥&__Dbg_flg gt 0
        ld24    r1,#__Dbg_mode
;       ldi     r2,#0
        ldi     r2,#4
        stb     r2,@r1
        .AENDI
```

The value to set to R2 register is ‘0’ (AFTER mode) or ‘2’ (BREAK mode).

6.8 System Clock Settings

6.8.1 Register system clock handler

The system clock handler(__sys_timer assembly language routine) must be registered to MR32R as an interrupt handler in configuration file when the system clock is used.

For example,if there are 64 factor of interrupts from factor number 0 to 63 and factor number 16 is a system clock, you must describe as below.

interrupt_vector[16] = __sys_timer;

Precautions about system clock handler

- **When timer-initializing template file "m32160.tpl" for the M32160 group MCUs is used**
  When timer-initializing template file "m32160.tpl" for the M32160 group MCUs is used, timer interrupt share the same interrupt entry. So, the judgement program which timer interrupt occured is needed. It is the interrupt handler defined in the item of the interrupt handler in configurationfile.
  The system clock interrupt handler must be called from the judgement program when a system clock interrupt occurred.
  (“bl” instruction must be used. “bra” instruction must not be used when __sys_timer is called.)
- The external interrupt must be disabled(clear IE bit of PSW register) when the system clock interrupt handler is called.

6.8.2 Automatic system clock settings

The structure of system clock settings

MR32R supports automatic system clock settings(e.q. timer initialize,ICU settings) for several kind of M32R microcomputers.
The following is the structure of system clock settings. At first, the template file name, the timer name, interval of timer interrupt and the timer operating clock frequency are describe in the configuration file. Then the configurator copies template file from the directory specified “LIB32R” environment variable to the current directory as “timer.inc” and outputs the timer name , the interval of timer interrupt and the timer operating clock frequency defined as symbols in “mr32r.inc”. “timer.inc” file is included by”ipl.ms” file and the system timer is initialized by using the symbol definitions in ”mr32r.inc”.
(You can re-use “ipl.ms” file used as before. The template file name and the kind of supported micro computers are shown in the Fig.6-3 .If your micro computer is not supported, please make this file as “ipl.ms”)

Precautions about automatic timer settings

- **When automatic timer settings function is used**
  Execute configurator with “-I” option sommand.
  The configurator does not copy “timer.inc” when “timer.inc” file already exists in current directory.
  The configurator does not check the overflow of the timer count value.
- **When automatic timer settings function is not used**
  Make an interrupt control program “ipl.ms” when TM is not used and the configurator is executed with “-m” command option. If you don’t make it, compile error may occure after makefile generated.
  (See sample “ipl.ms” in the sample program directory.)

6.9 Precautions about depending on compiler

6.9.1 When CC32R is used

- **The procedure of using CC32R base register function on MR32R**

The following is the procedure of using CC32R base register function on MR32R

1. Define base address.
2. Generate access control file.
3. **Define base symbols.**
   The base symbols are defined in start-up routine.
   <e.q> R11=0x00FC8000,R12=0x00F88000,R13=unused
   Modify start-up routine as below.(line 48 to line 66)

```
        .global  __REL_BASE11
        .global  __REL_BASE12
        .global  __REL_BASE13
__REL_BASE11:    .equ     0x00FC8000        <- 1. define base sumbols
__REL_BASE12:    .equ     0x00F88000
__REL_BASE13:    .equ     0

__START:
        seth     r1,#high(__Sys_Sp)
        or3      r1,r1,#low(__Sys_Sp)
        addi     r1,#-4
        mvtc     r1,SPI               ;SPI initialize
        mvtc     r1,SPU
        ldi      r0,#-1
        st       r0,@r1
        ldi      r0,#NULL
        mvtc     r0,PSW               ;PSW initialize

;       seth     R11,#high(__REL_BASE11)    <- 2.Set the value to base registers
;       or3      R11,R11,#low(__REL_BASE11)     when C function is called from
;       seth     R12,#high(__REL_BASE12)        start-up routine.
;       or3      R12,R12,#low(__REL_BASE12)
;       seth     R13,#high(__REL_BASE13)
;       or3      R13,R13,#low(__REL_BASE13)
```

(Caution)

- You need not to base register settings at the start of the tasksthe interrupt handlers and the cyclic handlers.
- **You must define the base symbols when base register function is not used. In this case, base register value is your discretion.**

4. Comple and link your program

6.9.2 When TW32R is used

- **Precaution about using with TM**
  The default library search path for MR32R kernel library is not registered. It must be register to TM clearly.

  1. Select “Project Settings” from ”Environment” of TM menu.
  2. Select “LIBRARY” tab of the ”Project Settings”.
  3. Select ”Path” button and specify the MR32R kernel library path.

  The MR32R library is installed “lib32rg” directory under the directory specified in installing. (When MR32R is installed to “c:¥mtool”, “c:¥mtool¥lib32rg” corresponding to the directory.)

6.9.3 When D-CC/M32R is used

- Precaution about the output of the dependence
  The configurator outputs warnings because it can’t output dependence of system include files when it is executed with “-m” command option.

  [Workaround]

  1. Copy the MR32R kernel include file “mr32r.h” to the system include directory of D-CC/M32R.

     [e.q.] copy %INC32RG%¥mr32r.h %DIABLIB%¥include

  2. Change the environment variable “INC32RG” to the system include directory of D-CC/M32R.

     [e.q.] set INC32RG=%DIABLIB%¥include

6.10 Memory mapping

6.10.1 Memory Allocation when Using CC32R

Here follows explanation as to the sections the OS uses when using CC32R.

- **Sections used when C is in use**
  - **P Section**
    This section is allocated for user application programs.
  - **B Section**
    This section is allocated for non-initial-valued data.
    This section must be allocated to RAM area.
  - **C Section**
    This section is allocated for constant data.
  - **D Section**
    This section is allocated for initial-valued data.
    This section must be transferred from ROM area to RAM area.
- **Sections for use with MR32R**
  - **SYS_STACK Section**
    This section is allocated for the system stack area. Some inner members of the kernel, the interrupt handlers, and the like use this section.
    This section must be allocated to RAM area.
  - **INT_USR_STACK Section**
    This is user stack area in the internal RAM.
  - **EXT_USR_STACK Section**
    This is user stack area in the external RAM.
  - **MR_KERNEL,MR_KERNEL2 Section**
    The OS's kernel uses this section.
  - **MR_RAM Section**
    This is the internal RAM data area used by MR32R.
  - **EXT_MR_RAM Section**
    This is the external RAM data area used by MR32R.
  - **MR_ROM Section**
    This section is allocated for fixed data the OS uses.
    This section must be transfer ROM area to RAM area when dynamic creation function is used.
  - **MR_HEAP Section**
    This is the internal RAM heap area used by MR32R.This section used when using valiable-size memorypool function.
  - **EXT_MR_HEAP Section**
    This is the external RAM heap area used by MR32R.This section used when using valiable-size memorypool function.
  - **MR_Dbg_RAM**
    This is the RAM area used by MR32R when OS debug function is used.

Sections related to interrupt vectors

- **Int_Vector Section**

- **EIT_Vector Section**
  This section is used for storing the EIT vector area.

- **RESET_VECT Section**
  This section is used for the reset vector area.

- **INTERRUPT_VECT Section**
  This section is used for interrupt vector table.
  This section must be transfer ROM area to RAM area when def_int system call is used.

6.10.2 Memory Allocation when Using TW32R/D-CC/M32R

Here follows explanation as to the sections the OS uses when using TW32R or D-CC/M32R.

- **Sections used when C is in use**

  - **.text Section**
    This section is allocated for user application programs.

  - **.bss, .sbss Section**
    This section is allocated for non-initial-valued data.
    This section must be allocated to RAM area.

  - **.rodata Section**
    This section is allocated for constant data.

  - **.sdata, .data Section**
    This section is allocated for initial-valued data.
    This section must be transferred from ROM area to RAM area.

- **Sections for use with MR32R**

  - **.SYS_STACK Section**
    This section is allocated for the system stack area. Some inner members of the kernel, the interrupt handlers, and the like use this section.
    This section must be allocated to RAM area.

  - **.INT_USR_STACK Section**
    This is user stack area in the internal RAM.

  - **.EXT_USR_STACK Section**
    This is user stack area in the external RAM.

  - **.MR_KERNEL,MR_KERNEL2 Section**
    The OS's kernel uses this section.

  - **.MR_RAM Section**
    This is the internal RAM data area used by MR32R.

  - **.EXT_MR_RAM Section**
    This is the external RAM data area used by MR32R.

  - **.MR_ROM Section**
    This section is allocated for fixed data the OS uses.
    This section must be transfer ROM area to RAM area when dynamic creation function is used.

  - **.MR_HEAP Section**
    This is the internal RAM heap area used by MR32R.This section used when using valiable-size memorypool function.

  - **.EXT_MR_HEAP Section**
    This is the external RAM heap area used by MR32R.This section used when using valiable-size memorypool function.

  - **.EXT_MR_HEAP Section**
    This is the external RAM heap area used by MR32R.This section used when using valiable-size memorypool function.

- **Sections related to interrupt vectors**
  - **.Int_Vector Section**
  - **.EIT_Vector Section**
    This section is used for storing the EIT vector area.
  - **.RESET_VECT Section**
    This section is used for the reset vector area.
  - **.INTERRUPT_VECT Section**
    This section is used for interrupt vector table.
    This section must be transfer ROM area to RAM area when def_int system call is used.

6.10.3 Memory Model

In MR32R, there are two kinds of following memory models.

- **Large model**

It is the model which can arrange the kernel area and data area of MR32R to the space exceeding 16MB. Only the M3 T-CC32R correspondence kernel is preparing the large model. There is the following restriction about the section arrangement at the time of large model correspondence.

*** Or it is not supporting EVB (EIT vector base register), the processing shown below is required of the microcomputer which cannot set EVB as the domain exceeding 16MB.**

- **None large model**

(a) The following sections can be mapped into areas beyond address 1000000H:

INT_USR_STACK, EXT_USR_STACK, SYS_STACK Section
EXT_MR_RAM, MR_HEAP, EXT_MR_HEAP Section

(b) The following sections cannot be mapped into areas beyond address 1000000H:

MR_RAM, MR_ROM, INTERRUPT_VECTOR, MR_Dbg_RAM Section
MR_KERNEL,MR_KERNEL2 Section

*** Or it is not supporting EVB (EIT vector base register), the processing shown below is required of the microcomputer which cannot set EVB as the domain exceeding 16MB.**
*** You have to arrange MR_KERNEL and MR_KERNEL2 in relative 16MB space.**

Whether the code sections (such as P and .text) and data sections (such as B, D, and C, or bss, .data, and .rodata) that applications use are mapped or not is compiler-dependent. Furthermore, it might be necessary for the mapping to change compiler options and linking standard libraries as well as reconfigure standard libraries. For details, refer to your compiler's manual.

6.10.4 Arrangement to Space Exceeding 16MB of Kernel Area

In MR32R, the TRAP command is used for the call of a system call. However, since there is only 4 bytes of entry, TRAP cannot be jumped to the space which exceeds 16MB directly.
therefore, on using the microcomputer which cannot set EVB (EIT vector base register) as the area exceeding 16MB or it is not supporting EVB, it is necessary to once jump in 16MB space and to jump by jmp and jl command to the space which exceeds 16MB from there.
The example of the TRAP7 used in system call processing in the case of having arranged the MR32R kernel area H'2000000 henceforth is shown in the following figure.

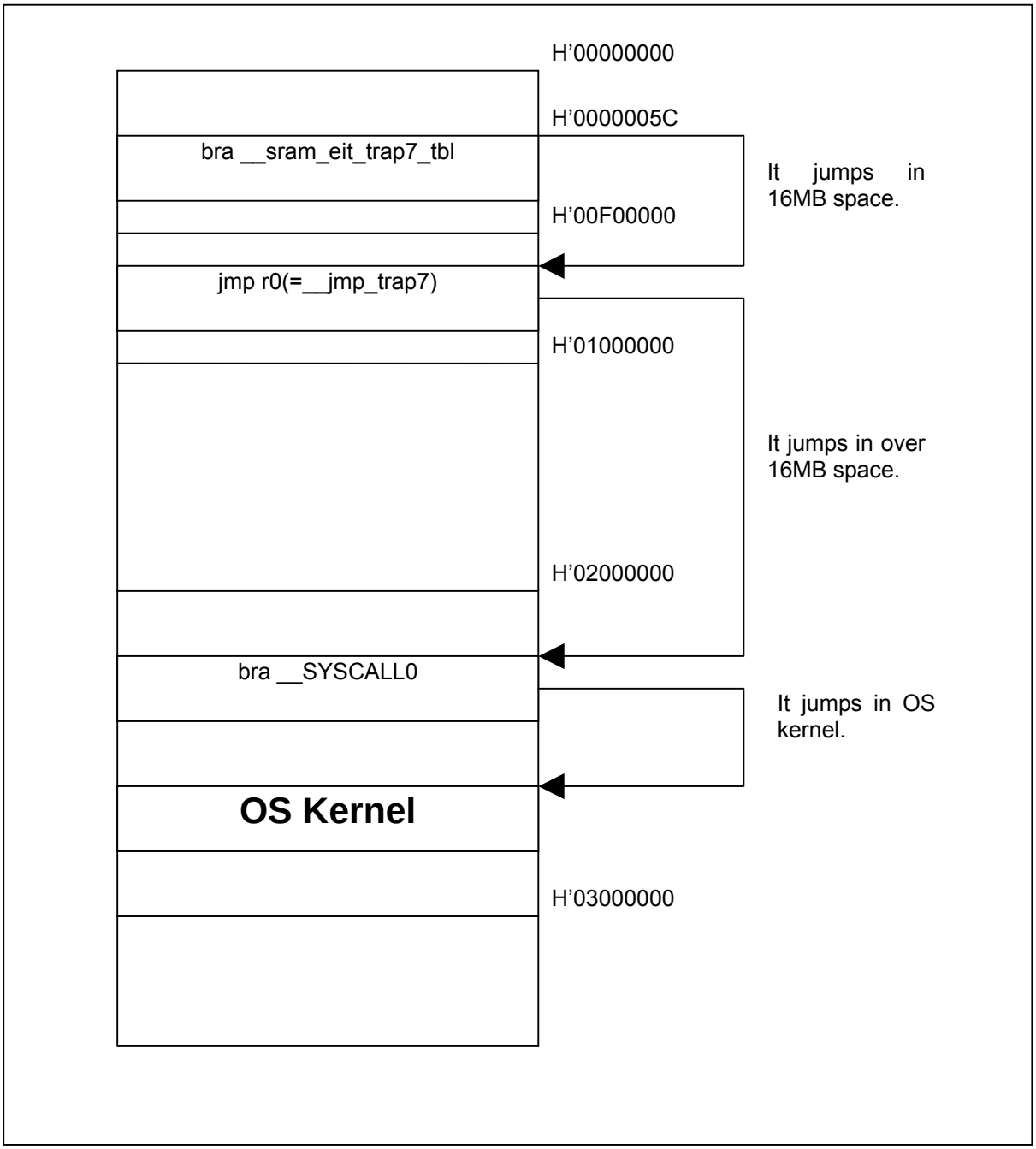


Figure 6.3 Allocate OS kernel to the over 16MB area

(1) A start-up routine is changed and the jump place of TRAP and EI vector is changed.

```
.global _sram_eit_trap7_tbl,_sram_eit_trap8_tbl
                :
bra     _sram_eit_trap7_tbl             ; TRAP7
bra     _sram_eit_trap8_tbl             ; TRAP8
                :
.section        Int_Vector,code,align=4
st      r0,@-r15
seth    r0,#high(_jmp_ei)
or3     r0,r0,#low(_jmp_ei)
jmp     r0
```

(2) The code for the 2nd step jump is added to a start-up routine. This section is arranged in 16MB space.

```
.section        ROM_MR_EIT,code,align=4
.section        MR_EIT,code,align=4
.export _sram_eit_trap7_tbl
_sram_eit_trap7_tbl:
st      r0,@-r15
seth    r0,#high(_jmp_trap7)
or3     r0,r0,#low(_jmp_trap7)
jmp     r0

.export _sram_eit_trap8_tbl
_sram_eit_trap8_tbl:
st      r0,@-r15
seth    r0,#high(_jmp_trap8)
or3     r0,r0,#low(_jmp_trap8)
jmp     r0
```

(3) The code for the 3rd step jump is added to a start-up routine. This section is taken as the same section (MR_KERNEL) as OS kernel area.

```
.section        MR_KERNEL
_jmp_trap7:
.AIF    ¥&__Dbg_flg eq 0
.global __SYSCALL0
ld      r0,@r15+
bra     __SYSCALL0
.AELSE
.global __Dbg_entry0
ld      r0,@r15+
bra __Dbg_entry0
.AENDI

_jmp_trap8:
.AIF    ¥&__Dbg_flg eq 0
.global __SYSCALL1
ld      r0,@r15+
bra __SYSCALL1
.AELSE
.global __Dbg_entry1
ld      r0,@r15+
bra __Dbg_entry1
.AENDI

_jmp_ei:
.global __int_entry
ld      r0,@r15+
bra __int_entry
```

Chapter 7 Using Configurator

7.1 Configuration File Creation Procedure

When applications program coding and startup program modification are completed, it is then necessary to register the applications program in the MR32R system.
This registration is accomplished by the configuration file.

7.1.1 Configuration File Data Entry Format

This chapter describes how the definition data are entered in the configuration file.

Comment Statement

A statement from '//' to the end of a line is assumed to be a comment and not operated on.

End of statement

Statements are terminated by ';'.

Numerical Value

Numerical values can be entered in the following format.

1. **Hexadecimal Number**

   Add "0x" or "0X" to the beginning of a numerical value, or "h" or "H" to the end. If the value begins with an alphabetical letter between A and F with "h" or "H" attached to the end, be sure to add "0" to the beginning. Note that the system does not distinguish between the upper- and lower-case alphabetical characters (A-F) used as numerical values.[61]

2. **Decimal Number**

   Use an integer only as in '23'. However, it must not begin with '0'.

3. **Octal Numbers**

   Add '0' to the beginning of a numerical value of 'O' or 'o' to end.

4. **Binary Numbers**

   Add 'B' or 'b' to the end of a numerical value. It must not begin with '0'.

Table 7.1Numerical Value Entry Examples

Hexadecimal	0xf12 0Xf12 0a12h 0a12H 12h 12H
Decimal	32
Octal	017 17o 17O
Binary	101110b 101010B

It is also possible to enter operators in numerical values. Table 7.2 lists the operators available.

Table 7.2Operators

[61] The system distinguishes between the upper- and lower-case letters except for the numbers A-F and a-f.

Operator	Priority	Direction of computation
()	High	From left to right
- (Unary_minus)		From right to left
* / %		From left to right
+ - (Binary_minus)	Low	From loft to right

Numerical value examples are presented below.

- 123
- 123 + 0x23
- (23=4 + 3) * 2
- 100B + 0aH

Symbol

The symbols are indicated by a character string that consists of numerals, upper- and lower-case alphabetical letters, _(underscore), and ?, and begins with a non-numeric character.
Example symbols are presented below.

- _TASK1
- IDLE3

Function Name

The function names are indicated by a character string that consists of numerals, upper and lower-case alphabetical letters,'$'(dollar) and '_'(underscore), begins with a non-numeric character, and ends with '()'.
The following shows an example of a function name written in the C language.

- main()
- func()

When written in the assembly language, the start label of a module is assumed to be a function name.

Frequency

The frequency is indicated by a character string that consist of numerals and . (period), and ends with MHz. The numerical values are significant up to six decimal places. Also note that the frequency can be entered using decimal numbers only.
Frequency entry examples are presented below.

- 16MHz
- 8.1234MHz

It is also well to remember that the frequency must not begin with . (period).

Time

The time is indicated by a character string that consists of numerals and . (period), and ends with ms or s. The time values are effective up to three decimal places when the character string is terminated with ms or up to six decimal places when the character string is terminated with s. Also note that the time can be entered using decimal numbers only.

- 0.23s
- 10ms
- 10.5ms

It is also well to remember that the time must not begin with . (period).

The time of day

The time of day is expressed using 3-word (48-bit) data which consists of 1-word (16-bit) numbers joined with : (colon), as shown in the example below.

- 23 : 0x02 : 100B

If one or two high-order numbers of a total of three numbers are omitted, the omitted numbers are regarded as 0. For instance, 12 is equivalent to 0:0:12.

7.1.2 Configuration File Definition Items

The following definitions [62] are to be formulated in the configuration file

- System definition
- System clock definition
- Respective maximum number of items
- Dynamically creating user stack area definition
- Dynamically creating mailbox area definition
- Dynamically creating message buffer area definition
- Dynamically creating fixed-size memory pool area definition
- Dynamically creating variable-size memory pool area definition
- Task definition
- Eventflag definition
- Semaphore definition
- Mailbox definition
- Messagebuffer definition
- Rendezvous definition
- Fixed-size Memorypool definition
- Variable-size Memorypool definition
- Cyclic handler definition
- Alaram handler definition
- Interrupt vector definition
- Mailbox with priority definition

[62] All items except task definition can omitted. If omitted, definitions in the default configuration file are referenced.

System Definition Procedure

<< Format >>

```
// System Definition
system{
    stack_size      = System stack size ;
    priority        = Maximum value of priority ;
    exc_handler     = Interrupt handler ;
    debug           = Debug function;
    debug_buffer    = Buffer size for debug function;
 };
```

<< Content >>

1. **System stack size**

   [(Definition format)] Numeric value

   [(Definition range)] 1 or more

   Define the total stack size used in system call and interrupt processing.

2. **Maximum value of priority (value of lowest priority)**

   [(Definition format)] Numeric value

   [(Definition range)] 1 ~ 255

   Define the maximum value of priority used in MR32R's application programs. This must be the value of the highest priority used.

3. **Exception handler**

   [(Definition format)] Symbol

   [(Definition range)] YES or NO

   If a forced exception handler is defined in application program, set YES in this section.If not defined, set NO in this section.

4. **Debug function**

   [(Definition format)] Symbol

   [(Definition range)] YES or NO

   If you use MR trace function or system call issuance function in a debugger which supports OS debug function (ex. PD32R), set YES in this section.If not use, set NO in this section.
   By setting YES, MR32R calls the hook routines to support OS debug function.

5. **Buffer size for OS debug function**

   [(Definition format)] Numeric value

   [(Definition range)] 0 or more(multiple of four)

   Specify the buffer size for OS debug functio.If you secure 4096 bytes,about 60 times dispatching or more can be traced.

- **Dynamically creating user stack area definition (internal RAM)**

```
<< Format >>

int_memstk{
    max_memsize     = Maximum size of task stack to be created;
    all_memsize     = Size of the task creating user stack area (internal RAM);
};
```

<< Content >>

1. **Maximum size of task stack to be created**

   [(Definition format)] Numeric value

   [(Definition range)] 1 or more

   Specify the maximum value of stack size among tasks created by issuing the cre_tsk system call or the exception handlers defined by def_exc. For this value, specify the largest stack size among tasks for which the internal RAM has been specified for use as the stack.

2. **Size of the task creating user stack area (internal RAM)**

   [(Definition format)] Numeric value

   [(Definition range)] 192 or more

   Specify the size of the user stack area that is used to create tasks.
   The area of the specified size here is necessary to allocate the stack area (internal RAM) for tasks that are required when creating the task.
   A size of memory required for the stack specified by the cre_tsk system call is allocated from this user stack area.

- **Dynamically creating user stack area definition (external RAM)**

```
<< Format >>

ext_memstk{
    max_memsize     = Maximum size of task stack to be created ;
    all_memsize     = Size of the task creating user stack area (external RAM);
};
```

<< Content >>

1. **Maximum size of task stack to be created**

   [(Definition format)] Numeric value

   [(Definition range)] 1 or more

   Specify the maximum value of stack size among tasks created by issuing the cre_tsk system call or the exception handlers defined by def_exc. For this value, specify the largest stack size among tasks for which external RAM has been specified for use as the stack.

2. **Size of the task creating user stack area (external RAM)**

   [(Definition format)] Numeric value

   [(Definition range)] 192 or more

   Specify the size of the user stack area that is used to create tasks.

The area of the specified size here is necessary to allocate the stack area (external RAM) for tasks that are required when creating the task.
A size of memory required for the stack specified by the cre_tsk system call is allocated from this user stack area.

- **Dynamically creating mailbox area definition (internal RAM)**

```
<< Format >>

int_memmbx{
    max_memsize     = Maximum size of mailbox to be created;
    all_memsize     = Size of the dynamically creating mailbox area (internal RAM);
};
```

<< Content >>

1. **Maximum size of mailbox to be created**

   [(Definition format)] Numeric value

   [(Definition range)] 1 or more

   Specify the maximum value of mailbox size among those created by issuing the cre_mbx system call. For this value, specify the largest size among mailboxes for which the internal RAM has been specified.

2. **Size of the dynamically creating mailbox area (internal RAM)**

   [(Definition format)] Numeric value

   [(Definition range)] 192 or more

   Specify the size of a dynamically creating mailbox area.
   The area of the specified size here is necessary to allocate a mailbox area (internal RAM) when issuing the cre_mbx system call.
   A size of memory required for the mailbox specified by the cre_mbx system call is allocated from this dynamically creating mailbox area.

- **Dynamically creating mailbox area definition (external RAM)**

```
<< Format >>

ext_memmbx{
    max_memsize     = Maximum size of mailbox to be created;
    all_memsize     = Size of the dynamically creating mailbox area (external RAM);
};
```

<< Content >>

1. **Maximum size of mailbox to be created**

   [(Definition format)] Numeric value

   [(Definition range)] 1 or more

   Specify the maximum value of mailbox size among those created by issuing the cre_mbx system call. For this value, specify the largest size among mailboxes for which external RAM has been specified.

2. Size of the dynamically creating mailbox area (external RAM)

[(Definition format)] Numeric value

[(Definition range)] 192 or more

Specify the size of a dynamically creating mailbox area.
The area of the specified size here is necessary to allocate a mailbox area (external RAM) when issuing the cre_mbx system call.
A size of memory required for the mailbox specified by the cre_mbx system call is allocated from this dynamically creating mailbox area.

- **Dynamically creating message buffer area definition (internal RAM)**

<< Format >>

```
int_memmbf{
    max_memsize     = Maximum size of messagebuffer to be created;
    all_memsize     = Size of dynamically creating messagebuffer area (internal RAM);
};
```

<< Content >>

1. Maximum size of messagebuffer to be created

[(Definition format)] Numeric value

[(Definition range)] 1 or more

Specify the maximum value of messagebuffer size among those created by issuing the cre_mbf system call. For this value, specify the largest size among messagebuffers for which the internal RAM has been specified.

2. Size of dynamically creating messagebuffer area (internal RAM)

[(Definition format)] Numeric value

[(Definition range)] 192 or more

Specify the size of a dynamically creating messagebuffer area.
The area of the specified size here is necessary to allocate a messagebuffer area (internal RAM) when issuing the cre_mbf system call.
A size of memory required for the messagebuffer specified by the cre_mbf system call is allocated from this dynamically creating messagebuffer area.

- **Dynamically creating message buffer area definition (external RAM)**

<< Format >>

```
ext_memmbf{
    max_memsize     = Maximum size of messagebuffer to be created;
    all_memsize     = Size of dynamically creating messagebuffer area (external RAM);
};
```

<< Content >>

1. **Maximum size of messagebuffer to be created**

   [(Definition format)] Numeric value

   [(Definition range)] 1 or more

   Specify the maximum value of messagebuffer size among those created by issuing the cre_mbf system call. For this value, specify the largest size among messagebuffers for which external RAM has been specified.

2. **Size of dynamically creating messagebuffer area (external RAM)**

   [(Definition format)] Numeric value

   [(Definition range)] 192 or more

   Specify the size of a dynamically creating messagebuffer area.
   The area of the specified size here is necessary to allocate a messagebuffer area (external RAM) when issuing the cre_mbf system call.
   A size of memory required for the messagebuffer specified by the cre_mbf system call is allocated from this dynamically creating messagebuffer area.

● **Dynamically creating fixed-size memory pool area definition (internal RAM)**

<< Format >>

```
int_memmpf{
    max_memsize     = Maximum size of fixed-size memorypool to be created;
    all_memsize     = Size of dynamically creating fixed-size memorypool area (internal RAM);
};
```

<< Content >>

1. **Maximum size of fixed-size memorypool to be created**

   [(Definition format)] Numeric value

   [(Definition range)] 1 or more

   Specify the maximum value of fixed-size memorypool size among those created by issuing the cre_mpf system call. For this value, specify the largest size among fixed-size memorypools for which the internal RAM has been specified.

2. **Size of dynamically creating fixed-size memorypool area (internal RAM)**

   [(Definition format)] Numeric value

   [(Definition range)] 192 or more

   Specify the size of a dynamically creating fixed-size memorypool area.
   The area of the specified size here is necessary to allocate a fixed-size memorypool area (internal RAM) when issuing the cre_mpf system call.
   A size of memory required for the fixed-size memorypool specified by the cre_mpf system call is allocated from this dynamically creating fixed-size memorypool area.

● **Dynamically creating fixed-size memory pool area definition (external RAM)**

```
<< Format >>

ext_memmpf{
    max_memsize     = Maximum size of fixed-size memorypool to be created;
    all_memsize     = Size of dynamically creating fixed-size memorypool area (external RAM);
};
```

<< Content >>

1. **Maximum size of fixed-size memorypool to be created**

   [(Definition format)] Numeric value

   [(Definition range)] 1 or more

   Specify the maximum value of fixed-size memorypool size among those created by issuing the cre_mpf system call. For this value, specify the largest size among fixed-size memorypools for which external RAM has been specified.

2. **Size of dynamically creating fixed-size memorypool area (external RAM)**

   [(Definition format)] Numeric value

   [(Definition range)] 192 or more

   Specify the size of a dynamically creating fixed-size memorypool area.
   The area of the specified size here is necessary to allocate a fixed-size memorypool area (external RAM) when issuing the cre_mpf system call.
   A size of memory required for the fixed-size memorypool specified by the cre_mpf system call is allocated from this dynamically creating fixed-size memorypool area.

● **Dynamically creating variable-size memory pool area definition (internal RAM)**

```
<< Format >>

int_memmpl{
    max_memsize   = Maximum size of variable-size memorypool to be created;
    all_memsize   = Size of dynamically creating variable-size memorypool area (internal RAM);
};
```

<< Content >>

1. **Maximum size of variable-size memorypool to be created**

   [(Definition format)] Numeric value

   [(Definition range)] 1 or more

   Specify the maximum value of variable-size memorypool size among those created by issuing the cre_mpl system call. For this value, specify the largest size among variable-size memorypools for which the internal RAM has been specified.

2. **Size of dynamically creating variable-size memorypool area (internal RAM)**

   [(Definition format)] Numeric value

   [(Definition range)] 192 or more

   Specify the size of a dynamically creating variable-size memorypool area.

The area of the specified size here is necessary to allocate a variable-size memorypool area (internal RAM) when issuing the cre_mpl system call.
A size of memory required for the variable-size memorypool specified by the cre_mpl system call is allocated from this dynamically creating variable-size memorypool area.

● **Dynamically creating variable-size memory pool area definition (external RAM)**

<< Format >>

```
ext_memmpl{
    max_memsize   = Maximum size of variable-size memorypool to be created;
    all_memsize   = Size of dynamically creating variable-size memorypool area (external RAM);
};
```

<< Content >>

1. Maximum size of variable-size memorypool to be created

[(Definition format)] Numeric value

[(Definition range)] 1 or more

Specify the maximum value of variable-size memorypool size among those created by issuing the cre_mpl system call. For this value, specify the largest size among variable-size memorypools for which external RAM has been specified.

2. Size of dynamically creating variable-size memorypool area (external RAM)

[(Definition format)] Numeric value

[(Definition range)] 192 or more

Specify the size of a dynamically creating variable-size memorypool area.
The area of the specified size here is necessary to allocate a variable-size memorypool area (external RAM) when issuing the cre_mpl system call.
A size of memory required for the variable-size memorypool specified by the cre_mpl system call is allocated from this dynamically creating variable-size memorypool area.

● **System Clock Definition Procedure**

<< Format >>

```
// System Clock Definition
clock{
    timer_clock     = Timer clock ;
    timer           = Timers mode;
    IPL             = System clock interrupt priority level;
    unit_time       = Unit time of system clock;
    initial_time    = Initial value of system time;
    file_name       = Template file name of timer setting;
};
```

<< Content >>

1. Timer clock

[(Definition format)] Frequency(in MHz)

[(Definition range)] None

Define the timer operating clock frequency.You can also use ”mpu_clock” for compatibility.

2. Timer

[(Definition format)] Symbol

[(Definition range)] OTHER, NOTIMER, or other symbol

Define timer mode by use of OTHER, NOTIMER,or other symbol. Use NOTIMER in using no timer.The symbol defined here is output in “mr32r.inc” as a symbol definition and is used for Macro expansion in the initial definition of “timer.inc”.

3. System clock interrupt priority level

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 6

Define the priority level of the system clock timer interrupt.
Interrupts whose priority levels are below the interrupt level defined here are not accepted during system clock interrupt handler processing.

4. Unit time of system clock

[(Definition format)] Time(in ms)

[(Definition range)] 0.1ms or more

Define the unit time of the system clock (system clock interrupt generation intervals) in ms.

5. Initial value of system time

[(Definition format)] Time of day

[(Definition range)] 0 : 0 : 0 ~ 0x7FFF : 0xFFFF : 0xFFFF

Define the initial value of the system time. If you do not use the functions based on system time (e.g., set_tim, get_tim, alarm handler), there is no need to set this item. If this item is not defined, system clock interrupt handler processing is optimized automatically. Note, however, that if a default value is defined in the default configuration file, said processing is not optimized.

6. Template file name

[(Definition format)] Symbol

[(Definition range)] nothing

Specify template file name used.The configrator copies the file specified to current directory as “timer.inc”. Correspondence between microcomputer and template fileis below.

Table 7.3 Correspondence between microcomputer and template file

Microcomputer	Template file	Symbol
M32120	m32120.tpl	MFT00,MFT001…MFT13
M32160	m32160.tpl	TOP0,TOP1,TOP2….TOP5
M32180	m32180.tpl	TOP0,TOP1....TOP10
Hint HM1	hint1.tpl	T0,T1
M65439	m65439.tpl	T0,T1,T2,MSA2000
M32102	m32102.tpl	MFT00,MFT001…MFT13

● **Definition respective maximum numbers of items**

Defines maximum number of each definition in applications[63]

<< Format >>

```
// Max Definition
maxdefine{
    max_task = the maximum number of tasks defined;
    max_flag = the maximum number of eventflags defined;
    max_mbx  = the maximum number of mailboxes defined;
    max_sem  = the maximum number of semaphores defined;
    max_mbf  = the maximum number of messagebuffer defined;
    max_por  = the maximum number of rendezvous defined;
    max_vmbx = the maximum number of mailbox with priority;
    max_mpf  = the maximum number of fixed-size memorypools defined;
    max_mpl  = the maximum number of variable-size memorypools defined;
    max_cyh  = the maximum number of cyclic handlers defined;
    max_alh  = the maximum number of alarm handlers defined;
    max_int  = the maximum number of interrupt handlers defined;
};
```

[63] The maximum number of OS objects must be defined when the system call which generate a task or OS objects(cre_xxx).

<< Contents >>

1. **The maximum number of tasks defined**

   [(Definition format)] Numeric value

   [(Definition range)] 1 ~ 32767

   Define the maximum number of tasks defined.

2. **The maximum number of eventflags defined**

   [(Definition format)] Numeric value

   [(Definition range)] 1 ~ 32766

   Define the maximum number of eventflags defined.

3. **The maximum number of mailboxes defined**

   [(Definition format)] Numeric value

   [(Definition range)] 1 ~ 32766

   Define the maximum number of mailboxes defined.

4. **The maximum number of semaphores defined**

   [(Definition format)] Numeric value

   [(Definition range)] 1 ~ 32766

   Define the maximum number of semaphores defined.

5. **The maximum number of messagebuffer defined**

   [(Definition format)] Numeric value

   [(Definition range)] 1 ~ 32765

   Define the maximum number of messagebuffer defined.

6. **The maximum number of rendezvous defined**

   [(Definition format)] Numeric value

   [(Definition range)] 1 ~ 32765

   Define the maximum number of rendezvous defined.

7. The maximum number of mailbox with priority defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 32765

Define the maximum number of mailbox with priority.

8. The maximum number of fixed-size memorypools defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 32766

Define the maximum number of fixed-size memorypools defined.

9. The maximum number of variable-size memorypools defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 32766

Define the maximum number of variable-size memorypools defined.

10. The maximum number of cyclic activation handlers defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 32767

The maximum number of cyclic handler defined

11. The maximum number of alarm handler defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 32767

Define the maximum number of alarm handlers defined.

12. The maximum number of interrupt handler defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 255

Define the maximum number of interrupt handlers defined.

● Task definition

<< Format >>

```
 // Tasks Definition
task[ ID No. ]{
    entry_address   = Start task of address ;
    stack_size      = User stack size of task ;
    stack_area      = User stack area of task ;
    stack_area      = User stack section name of task ;
    priority        = Initial priority of task ;
    initial_start   = Initial startup status ;
};
            :
            :
```

The ID number must be in the range of 1 to 32767. The ID number can be omitted.
If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>
Define the following for each task ID number.

1. **Start address of task**

   [(Definition format)] Symbol or function name

   [(Definition range)] None

   Define the entry address of a task. When written in the C language, add () at the end , _ or $ at the beginning of the function name you have defined.

2. **User stack size of task**

   [(Definition format)] Numeric value

   [(Definition range)] 80 or more

   Define the user stack size for each task. The user stack means a stack area used by each individual task. MR32R requires that a user stack area be allocated for each task, which amount to at least 80 bytes.
   Also, If the forced exception handler is defined for a task by this definition,it needs further 96 .
   The numerical value you specify will be rounded to a multiple of four.

3. **Stack location**

   [(Definition format)] Symbol

   [(Definition range)] __MR_INT or __MR_EXT

   Specify the location of the user stack. Specifically this means specifying whether you want the user stack to be located in the internal RAM or in external RAM.
   - **To locate the user stack in the internal RAM**
     Specify __MR_INT.
   - **To locate the user stack in external RAM**
     Specify __MR_EXT.

   If this item is omitted, __MR_INT is set by default.
   If you specify stack_section in item 4, be sure to omit specification of this item.

4. Stack section name

[(Definition format)] Symbol

[(Definition range)] None

Specify the section name in which you want to locate the task stack. The sections defined here must always be located using the section file.
If you specify stack_area in item 3, be sure to omit specification of this item.

5. Initial priority of task

[(Definition format)] Numeric value

[(Definition range)] 1 to (maximum value of priority in system definition)

Define the priority of a task at startup time.
As for MR32R's priority, the lower the value, the higher the priority.

6. Initial startup status

[(Definition format)] Symbol

[(Definition range)] ON or OFF

If you specify ON, the task is placed in a READY state when the system initially starts up.

● Eventflag definition

<< Format >>

```
// Event Flag Definition
flag[ ID No. ]{
   name            = Name ;
};
            :
            :
```

The ID number must be in the range of 1 to 32766. The ID number can be omitted.
If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each eventflag ID number.

1. Name

[(Definition format)] Symbol

[(Definition range)] None

Define the name with which an eventflag is specified in a program.

● Semaphore definition

<< Format >>

```
 // Semaphore Definition
semaphore[ ID No. ]{
    name            = Name;
    max_count       = Maximum value of semaphore counter;
    initial_count   = Initial value of semaphore counter;
};
            :
            :
```

The ID number must be in the range of 1 to 32766. The ID number can be omitted.
If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each semaphore ID number.

1. **Name**

   [(Definition format)] Symbol

   [(Definition range)] None

   Define the name with which a semaphore is specified in a program.

2. **Maximum value of semaphore counter**

   [(Definition format)] Numeric value

   [(Definition range)] 0 ~ 0x7FFFFFFF

   Define the maximum value of the semaphore counter.

3. **Initial value of semaphore counter**

   [(Definition format)] Numeric value

   [(Definition range)] 0 ~ Maximum value of semaphore counter

   Define the initial value of the semaphore counter.

● Mailbox definition

<< Format >>

```
 // Mailbox Definition
mailbox[ ID No. ]{
    name            = Name;
    mbx_area        = Mailbox location;
    buffer_size     = Maximum number of mailbox messages;
};
            :
            :
```

The ID number must be in the range of 1 to 32766. The ID number can be omitted.
If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the name with which a mailbox is specified in a program.

1. **Name**

   [(Definition format)] Symbol

   [(Definition range)] None

   Define the name with which a mailbox is specified in a program.

2. **Mailbox location**

   [(Definition format)] Symbol

   [(Definition range)] __MR_INT or __MR_EXT

   Specify the location of the mailbox. Specifically this means specifying whether you want the mailbox to be located in the internal RAM or in external RAM.
   - **To locate the mailbox in the internal RAM**
     Specify __MR_INT.
   - **To locate the mailbox in external RAM**
     Specify __MR_EXT.

   If this item is omitted, __MR_INT is set by default.

3. **The maximum number of messages**

   [(Definition format)] Numeric Value

   [(Definition range)] 1 or more

   Define the maximum number of messages that can be stored in a mailbox. An error is returned if an attempt is made to store messages exceeding this limit.

● Messagebuffer definition

<< Format >>

```
 // MessageBuffer Definition
message_buffer[ ID No. ]{
    name           = Name;
    mbf_area       = Messagebuffer location;
    buffer_size    = Maximum number of messagebuffer;
};
            :
            :
```

The ID number must be in the range of 1 to 32765. The ID number can be omitted.
If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the name with which a messagebuffer is specified in a program.

1. **Name**

   [(Definition format)] Symbol

   [(Definition range)] None

   Define the name with which a messagebuffer is specified in a program.

2. Messagebuffer location

[(Definition format)] Symbol

[(Definition range)] __MR_INT or __MR_EXT

Specify the location of the messagebuffer. Specifically this means specifying whether you want the messagebuffer to be located in the internal RAM or in external RAM.

- **To locate the messagebuffer in the internal RAM**
  Specify __MR_INT.
- **To locate the messagebuffer in external RAM**
  Specify __MR_EXT.

If this item is omitted, __MR_INT is set by default.

3. Maximum number of messagebuffer

[(Definition format)] Numeric Value

[(Definition range)] 0 or more

Specify a messagebuffer size. The numerical value you specify will be rounded to a multiple of four.

● Rendezvous definition

<< Format >>

```
// Rendezvous Definition
rendezvous [ ID No. ]{
   name            = Name;
};
            :
            :
```

The ID number must be in the range of 1 to 32765. The ID number can be omitted.
If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the name with which a port for rendezvous is specified in a program.

1. Name

[(Definition format)] Symbol

[(Definition range)] None

Define the name with which a port for rendezvous is specified in a program.

● Mailbox definition with priority

<< Format >>

```
 // Mailbox Definition
vmailbox[ ID No. ]{
    name            = Name ;
    wait_queue      = The order of receiving message;
    message_queue   = The order of sending message;
    maxpri          = Maximum priority of mailbox messages;
};
            :
            :
```

The ID number must be in the range of 1 to 32765. The ID number can be omitted.
If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the name with which a mailbox is specified in a program.

2. Name

[(Definition format)] Symbol

[(Definition range)] None

Define the name with which a mailbox is specified in a program.

3. The order of receiving message

[(Definition format)] Symbol

[(Definition range)] FIFO or PRI

Specify the order of receiving message.

- **FIFO**
  Connects the task in FIFO order.
- **PRI**
  Connects the task in priority order.

If this item is omitted, FIFO is set by default.

4. The order of sending message

[(Definition format)] Symbol

[(Definition range)] FIFO or PRI

Specify the order of sending message.

- **FIFO**
  Connects the message in FIFO order.
- **PRI**
  Connects the message in priority order.

If this item is omitted, FIFO is set by default.

5. The maximum priority of messages

[(Definition format)] Numeric Value

[(Definition range)] 1 - 255

Define the maximum priority of messages. No error is returned if an attempt is made to spec-

ify priority value exceeding the maximum priority of messages.

● Fixed-size memorypool definition

<< Format >>

```
 // Fixed Memory Pool Definition
memorypool[ ID No. ]{
    name            = Name ;
    mpf_area        = Fixed-size Memorypool location ;
    section         = Section Name ;
    num_block       = Number of blocks for Memorypool ;
    siz_block       = Block size of Memorypool ;
};
            :
            :
```

The ID number must be in the range of 1 to 32766. The ID number can be omitted.
If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each memorypool ID number.

1. Name

[(Definition format)] Symbol

[(Definition range)] None

Define the name with which a memorypool is specified in a program.

2. Fixed-size Memorypool location

[(Definition format)] Symbol

[(Definition range)] __MR_INT or __MR_EXT

Specify the location of the fixed-size memorypool. Specifically this means specifying whether you want the fixed-size memorypool to be located in the internal RAM or in external RAM.

- To locate the fixed-size memorypool in the internal RAM
  Specify __MR_INT.
- To locate the fixed-size memorypool in external RAM
  Specify __MR_EXT.

If this item is omitted, __MR_INT is set by default.
If you specify section in item 3, be sure to omit specification of this item.

3. Section name

[(Definition format)] Symbol

[(Definition range)] None

Define the section name allocated memorypool. Be sure to allocate this section in your section file.
If you specify mpf_area in item 2, be sure to omit specification of this item.

4. **Number of block**

   [(Definition format)] Numeric value

   [(Definition range)] 1~32

   Define all Number of block for memorypool.

5. **Size**

   [(Definition format)] Numeric value

   [(Definition range)] 1 or more

   Define the size of one memorypool block. When this definition is formulated, the RAM capacity of the memorypool is set to (number of blocks) x (size).

- **Variabel-size memorypool definition**

<< Format >>

```
// Variable-Size Memory Pool Definition
variable_memorypool[ ID No. ]{
    name           = Name ;
    mpl_area       = Variable-size Memorypool location ;
    max_memsize    = The maximum memory block size to be allocated;
    heap_size      = Memorypool size ;
};
           :
           :
```

The ID number must be in the range of 1 to 32766. The ID number can be omitted.
If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

1. **Name**

   [(Definition format)] Symbol

   [(Definition range)] None

   Define the name with which a memorypool is specified in a program.

2. **The maximum memory block size to be allocated**

   [(Definition format)] Numeric value

   [(Definition range)] 0 or more

   Specify, within an application program, the maximum memory block size to be allocated.

3. **Variable-size Memorypool location**

   [(Definition format)] Symbol

   [(Definition range)] __MR_INT or __MR_EXT

   Specify the location of the variable-size memorypool. Specifically this means specifying whether you want the variable-size memorypool to be located in the internal RAM or in external RAM.

   - **To locate the variable-size memorypool in the internal RAM**

Specify __MR_INT.

- **To locate the variable-size memorypool in external RAM**
  Specify __MR_EXT.

If this item is omitted, __MR_INT is set by default.

4. Memorypool size

[(Definition format)] Numeric value

[(Definition range)] 192 or more

Specify a memorypool size. The numerical value you specify will be rounded to a multiple of four.

● Cyclic handler definition

<< Format >>

```
// Cyclic Handlar Definition
 cyclic_hand[ ID No. ]{
    interval_counter        = Intervals ;
    mode                    = Mode;
    entry_address           = Start address;
 };
            :
            :
```

The ID number must be in the range of 1 to 32767. The ID number can be omitted.
If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each cyclic handler ID number.

1. Intervals

[(Definition format)] Numeric value

[(Definition range)] 1 to 65535

Define the intervals at which time the cyclic handler is activated periodically. The intervals here must be defined in the same unit of time as the system clock's unit time that is defined in system clock definition item. If the system clock's unit time is 10 ms and you want the cyclic handler to be activated at 10-second intervals, for example, the intervals here must be set to 1000.

2. Mode

[(Definition format)] Symbol

[(Definition range)] TCY_ON or TCY_OFF

Define the initial mode of the cyclic handler. One of the following two modes can be defined here:

- TCY_OFF

In this mode, the cyclic handler is activated by a act_cyc system call.

- TCY_ON

In this mode, the cyclic handler is activated simultaneously when the system starts up.

3. Start Address

[(Definition format)] Symbol or Function Name

[(Definition range)] None

Define the start address of the cyclic handler.

● Alarm handler definition

<< Format >>

```
// Alarm Handlar Definition
alarm_hand[ ID No. ]{
    time            = Startup time;
    entry_address   = Start address;
};
            :
            :
```

The ID number must be in the range of 1 to 32767. The ID number can be omitted.
If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each alarm handler ID number.

1. Startup time

[(Definition format)] Time of day

[(Definition range)] 0 : 0 ~ 0x7FFF : 0xFFFFFFFF

Define the startup time of the alarm handler.

2. Start address

[(Definition format)] Symbol or Function Name

[(Definition range)] None

Define the start address of the alarm handler.

● Systemcall definition

<< Format >>

```
// Systemcall Definition
    systemcall{
            Systemcall Name = YES or NO;
};
            :
            :
```

Define a system call to be used in an application program as given below.

<< Content >>

1. Used system call

[(Definition format)] Symbol

[(Definition range)] YES or NO

Define a system call to be used in an application program as given below.
cre_tsk,del_tsk,sta_tsk,ista_tsk,ext_tsk,exd_tsk,ter_tsk,dis_dsp,ena_dsp,chg_pri,ichg_pri,rot_rdq,irot_rdq,rel_wai,irel_wai,get_tid,ref_tsk,sus_tsk,isus_tsk,rsm_tsk,irsm_tsk,slp_tsk,wup_tsk,iwup_tsk,can_wup,cre_flg,del_flg,set_flg,iset_flg,clr_flg,wai_flg,twai_flg,pol_flg,ref_flg,cre_sem,del_sem,sig_sem,isig_sem,wai_sem,twai_sem,preq_sem,ref_sem,cre_mbx,del_mbx,snd_msg,isnd_msg,rcv_msg,trcv_msg,prcv_msg,ref_mbx,cre_mbf,del_mbf,snd_mbf,tsnd_mbf,psnd_mbf,rcv_mbf,trcv_mbf,prcv_mbf,ref_mbf,cre_por,del_por,cal_por,tcal_por,pcal_por,acp_por,tacp_por,pacp_por,fwd_por,rpl_rdv,ref_por,def_int,ret_int,loc_cpu,unl_cpu,cre_mpf,del_mpf,get_blf,tget_blf,pget_blf,rel_blf,ref_mpf,cre_mpl,del_mpl,get_blk,tget_blk,pget_blk,rel_blk,ref_mpl,set_tim,get_tim,dly_tsk,act_cyc,ref_cyc,ref_alm,get_ver,ref_sys,def_exc,vclr_ems,vset_ems,vras_fex,vcre_mbx,vdel_mbx,vsnd_mbx,visnd_mbx,vrcv_mbx,vtrcv_mbx,vprcv_mbx,vrst_mbx,vref_mbx

● Interrupt vector definition

<< Format >>

```
 // Interrupt Vector Definition
interrupt_vector[ Vector No. ] = Start address ;
            :
            :
```

<< Content >>

1. Start address

[(Definition format)] Symbol or function name

[(Definition range)] None

Specify the interrupt handler's start address. Put an interrupt factor number in square brackets [ ].
If you use system clock for MR32R,you must define the system clock interrupt handler in .cfg file as __sys_timer.
[Ex] interrupt _vector[20] = __sys_timer;

7.1.3 Configuration File Example

The following is the configuration file example.

```
//
// Copyright(c)1998, 1999 MITSUBISHI ELECTRIC CORPORATION,
// And MITSUBISHI SEMICONDUCTOR SYSTEMS CORPORATION.
// MR32R Sample Configurator File.
//

// System Definition
system{
    stack_size      = 0x5000;
    priority        = 10;
    exc_handler     = NO;
};

//Max Definition
maxdefine{
    max_task        =       5;
    max_flag        =       1;
    max_mbx         =       1;
    max_sem         =       1;
    max_mem         =       1;
    max_cyh         =       2;
    max_alh         =       1;
    max_int         =       16;
};

//System Clock Definition
clock{
    timer_clock     =       33.3MHz;
    IPL             =       4;
    unit_time       =       1ms;
    timer           =       MFT00;
    file_name       =       m32102.tpl;
    initial_time    =       1:0x10ffff;
};

//Task Definition
task[1]{
    initial_start   =       ON;
    entry_address   =       task1();
    stack_size      =       0x1000;
    stack_area      =       __MR_INT;
    priority        =       2;
};

task[2]{
    entry_address   =       task2();
    stack_size      =       0x1000;
    stack_section   =       TASK2_STK;
    priority        =       3;
};

task[3]{
    entry_address   =       task3();
    stack_size      =       0x1000;
    stack_area      =       __MR_EXT;
    priority        =       4;
};

// Event Flag Definition
flag[1]{
    name            =       flg1;
```

```
};
// Semaphore Definiton
semaphore[1]{
    name            =       sem1;
    max_count       =       0x7ff;
    initial_count   =       0x0;
};
// MailBox Definition
mailbox[1]{
    name            =       mbx1;
    mbx_area        =       __MR_EXT;
    buffer_size     =       0x10;
};
// MessageBuffer Definition
message_buffer[1]{
    name            =       mbf;
    mbf_area        =       __MR_INT;
    buffer_size     =       0x10;
};
// Rendezvous Definition
rendezvous[1]{
    name            =       por1;
};
// Fixed-Memory pool Definition
memorypool[1]{
    name            =       mpf1;
    mpf_area        =       __MR_EXT;
    num_block       =       4;
    siz_block       =       0x100;
};
memorypool[2]{
    name            =       mpf2;
    section         =       MPF2_POOL;
    num_block       =       4;
    siz_block       =       0x100;
};
//Variable Memory  pool    Definition
variable_memorypool[]{
    name            =       mpl1;
    mpl_area        =       __MR_INT;
    max_memsize     =       0x500;
    heap_size       =       0x6000;
};

systemcall{
    cre_tsk         =       NO;
    del_tsk         =       NO;
    sta_tsk         =       YES;
    ter_tsk         =       YES;
    chg_pri         =       YES;
    rot_rdq         =       YES;
    rel_wai         =       YES;
    ena_dsp         =       YES;
    sus_tsk         =       YES;
    rsm_tsk         =       YES;
    slp_tsk         =       YES;
    wup_tsk         =       YES;
    set_flg         =       YES;
    wai_flg         =       YES;
    sig_sem         =       YES;
    wai_sem         =       YES;
    snd_msg         =       YES;
    rcv_msg         =       YES;
    snd_mbf         =       YES;
```

```
        rcv_mbf         =       YES;
        acp_por         =       YES;
        cal_por         =       YES;
        rpl_rdv         =       YES;
        get_blf         =       YES;
        rel_blf         =       YES;
        get_blk         =       YES;
        rel_blk         =       YES;
        unl_cpu         =       YES;
        dly_tsk         =       YES;
        ista_tsk        =       YES;
        ichg_pri        =       YES;
        irot_rdq        =       YES;
        irel_wai        =       YES;
        get_tid         =       YES;
        isus_tsk        =       YES;
        irsm_tsk        =       YES;
        iwup_tsk        =       YES;
        can_wup         =       YES;
        iset_flg        =       YES;
        clr_flg         =       YES;
        pol_flg         =       YES;
        isig_sem        =       YES;
        preq_sem        =       YES;
        isnd_msg        =       YES;
        prcv_msg        =       YES;
        set_tim         =       YES;
        get_tim         =       YES;
        act_cyc         =       YES;
        get_ver         =       YES;
        ret_int         =       NO;
        dis_dsp         =       YES;
        loc_cpu         =       YES;
        ext_tsk         =       YES;
        exd_tsk         =       NO;
    };
    //Interrupt Vector  Definition
        interrupt_vector[16]    =       __sys_timer;
    //
    //  End of Configuration
    //
```

7.2 Configurator Execution Procedures

7.2.1 Configurator Overview

The configurator is a tool that converts the contents defined in the configuration file into the assembly language include file, etc.Figure 7.1 outlines the operation of the configurator.

1. Executing the configurator requires the following input files:

- Configuration file (XXXX.cfg)
  This file contains description of the system's initial setup items. It is created in the current directory.

- Default configuration file (default.cfg)
  This file contains default values that are referenced when settings in the configuration file are omitted. This file is placed in the directory indicated by environment variable "LIB32R" or the current directory. If this file exists in both directories, the file in the current directory is prioritized over the other.

- makefile template files [64] (makefile.ews, makefile.dos, makefile, Makefile)
  This file is used as a template file when generating makefile.[65] (Refer to section 0).

- mr32r.inc template file(mr32r.inc)
  This file contains description of MR32R's version. It resides in the directory indicated by environment variable "LIB32R." The configurator reads in this file and outputs MR32R's version information to the startup message.

- The template files for initializing timer(XXX.tpl)
  A template file for initializing timer specified in configuration file is copied from “LIB32R” directory specified by environment variable to current directory as “timer.inc”.This file is included in ipl.ms(ipl.s).

- MR32R version file (version)
  This file contains description of MR32R's version. It resides in the directory indicated by environment variable "LIB32R." The configurator reads in this file and outputs MR32R's version information to the startup message.

2. When the configurator is executed, the files listed below are output.

Do not define user data in the files output by the configurator. Starting up the configurator after entering data definitions may result in the user defined data being lost.

- System data definition file (sys_rom.inc , sys_ram.inc)
  This file contains definition of system settings.

- Include file (mr32r.inc)
  This is an include file for the assembly language.

- System generation procedure description file(makefile)
  This file is used to generate the system automatically.

[64] The template file used for the EWS version is makefile.ews, and that for the DOS version is makefile.dos.
[65] This makefile is a system generation procedure description file that can be processed by UNIX standard make commands or those conforming to UNIX standards.

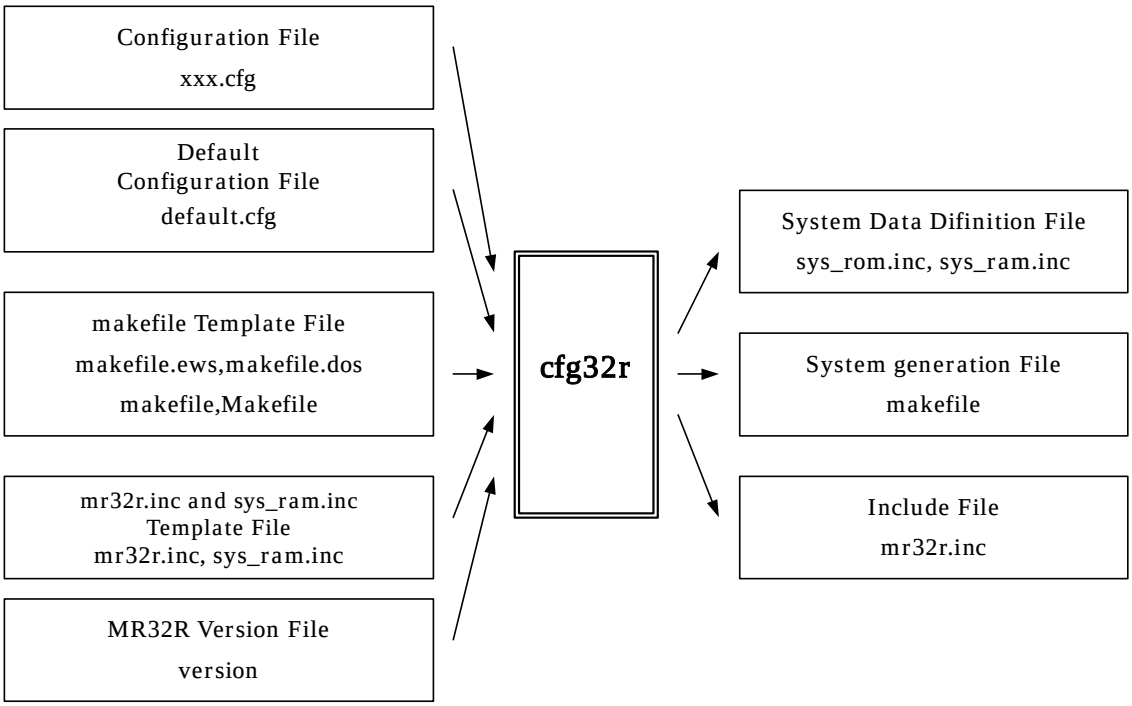


Figure 7.1 The operation of the Configurator

7.2.2 Setting Configurator Environment

Before executing the configurator, check to see if the environment variable "LIB32R" is set correctly. The configurator cannot be executed normally unless the following files are present in the directory indicated by the environment variable "LIB32R":

- Default configuration file (default.cfg)
  This file can be copied to the current directory for use. In this case, the file in the current directory is given priority.

- System RAM area definition database file (sys_ram.inc)
- mr32r.inc template file (mr32r.inc)
- Section definition file (section or m32r.cmd)
- makefile template file(makefile.ews or makefile.dos)
- MR32R version file (version)
- Startup file (crt0mr.ms,starut.ms or crt0mr.s)
- Interrupt control program (ipl.msor ipl.s)
- The template files for initializing timer(XXX.tpl)

7.2.3 Configurator Start Procedure

Start the configurator as indicated below.

```
A> cfg32r  [-vmiVR]  Configuration file name
```

Normally, use the extension .cfg for the configuration file name.

Command Options

-v Option

Displays the command option descriptions and detailed information on the version.

-V Option

Displays the information on the files generated by the command.

-R Option

Select this option to put a C-written function to the pass-by-register manner. With the TW32R or DCC/M32R used, this option is not available.

-i Option

A timer initialization file(“timer.inc”) is generated automatically.This file is not generated if it already exists.

-m Option

Creates the UNIX standard or UNIX-compatible system generation procedure description file (makefile). If this option is not selected, makefile creation does not occur.[66]
If the startup file and the section definition file are not in the current directory, the configurator copys them to the current directory form the directory indicated by the environment variable “LIB32R”.

[66] UNIX standard "makefile" and one conforming to UNIX standards have a function to delete the work file by a "clean" target. Namely,if you want to delete the object file generated by the make command,for example,enter the following:
> make clean

7.2.4 makefile generate Function

The configurator follows the procedure below to generate makefile.

1. Examine the source file's dependency relationship.

Assuming that the files bearing extensions .c and .ms or .s in the current directory respectively to be the C language and the assembly language files, the configurator examines the dependency relationship of the files to be included by those.

Consequently, observe the following precautions when creating a source file:

- The source file must be placed in the current directory.
- Use the extension '.c' for the C language source file and '.ms' or '.s' for the assembly language source file.

2. Write the file dependency relationship to makefile

Using "makefile" or "Makefile" in the current directory or "makefile.ews" or "makefile.dos" in the directory indicated by the environment variable "LIB32R" as a template file, the configurator creates "makefile" in the current directory.

7.2.5 Precautions on Executing Configurator

The following lists the precautions to be observed when executing the configurator

- If you have re-run the configurator, always be sure to execute make clean or delete all object files (extension .o or .mo) and execute the make command. In this case, an error may occur during linking.
- Do not modify the strartup program name and the section definition file name. Otherwise, an error may be encountered when executing the configurator.
- The configurator cfg32r can only generate UNIX standard makefile or one conforming to UNIX standards. Namely, it does not generate MS-DOS standard makefile.

7.2.6 Configurator Error Indications and Remedies

If any of the following messages is displayed, the configurator is not normally functioning. Therefore, correct the configuration file as appropriate and the execute the configurator again.

Error messages

cfg32r Error : syntax error near line 16 (test.cfg)
There is an syntax error in the configuration file.

cfg32r Error : not enough memory
Memory is insufficient.

cfg32r Error : illegal option --> <x>
The configurator's command option is erroneous.

cfg32r Error : illegal argument --> <xx>
The configurator's startup format is erroneous.

cfg32r Error : can't write open <XXXX>
The XXXX file cannot be created. Check the directory attribute and the remaining disk capacity available.

cfg32r Error : can't open <XXXX>
The XXXX file cannot be accessed. Check the attributes of the XXXX file and whether it actually exists.

cfg32r Error : can't open version file
The MR32R version file "version" cannnot be found in the directory indicated by the environment variable "LIB32R".

cfg32r Error : can't open default configuration file
The default configuration file cannnot be accessed. "default.cfg" is needed in the current directory or directory "LIB32R" specifying.

cfg32r Error : can't open configuration file <test.cfg>
The configuration file cannot be accessed. Check that the file name has been properly designated.

cfg32r Error : illegal XXXX --> <xx> near line 212 (test.cfg)
The value or ID number in definition item XXXX is incorrect. Check the valid range of definition.

cfg32r Error : Unknown XXXX --> <xx> near line 23 (test.cfg)
The symbol definition in definition item XXXX is incorrect. Check the valid range of definition.

cfg32r Error : too big XXXX's ID number --> <6> (test.cfg)
A value is set to the ID number in XXXX definition that exceeds the total number of objects defined.The ID number must be smaller than the total number of objects.

cfg32r Error : too big task[x]'s priority --> <16> (test.cfg)
The initial priority in task definition of ID number x exceeds the priority in system definition.

cfg32r Error : system timer's vector <x>conflict
A different vector is defined for the system clock timer interrupt vector. Confirm the vector

No.x for interrupt vector definition.

cfg32r Error : XXXX is not defined (test.cfg)
"XXXX" item must be set in your configuration file.

cfg32r Error : system's default is not defined
These items must be set int the default configuration file.

cfg32r Error : double definition <XXXX> near line 17 (test.cfg)
XXXX is already defined. Check and delete the extra definition.

cfg32r Error : double definition XXXX[x] near line 77 (default.cfg)

cfg32r Error : double definition XXXX[x] (test.cfg)
The ID number in item XXXX is already registered. Modify the ID number or delete the extra definition.

cfg32r Error : you must define XXXX near line 107 (test.cfg)
XXXX cannot be ommited.

cfg32r Error : you must define SYMBOL near line 30 (test.cfg)
This symbol cannnot be omitted.

cfg32r Error : start-up-file (XXXX) not found
The start-up-file XXXX cannot be found in the current directory. The startup file is required in the current directory.

cfg32r Error : bad start-up-file(XXXX)
There is unnecessary start-up-file in the current directory.

cfg32r Error : no source file
No source file is found in the current directory.

cfg32r Error : zero divide error near line 28 (test.cfg)
A zero divide operation occured in some arithmetic expression.

Warning messages

The following message are a warning. A warning can be ignored providing that its content is understood.

cfg32r Warning : system is not defined (test.cfg)

cfg32r Warning : system.XXXX is not defined (test.cfg)
System definition or system definition item XXXX is omitted in the configuration file.

cfg32r Warning : task[x].XXXX is not defined near line 32 (test.cfg)
The task definition item XXXX in ID number is omitted.

cfg32r Warning : Already definition XXXX near line 20 (test.cfg)
XXXX has already been defined.The defined content is ignored, check to delete the extra definition.

cfg32r Warning : specified variable memorypool.max`memsize 120 (test.cfg)
cfg32r specified max_memsize of the variable-size memorypool as 120, because you specified less than 120.

cfg32r Warning : interrupt`vector[x]'s default is not defined (default.cfg)
The interrupt vector definition of vector number x in the default configuration file is missing.

cfg32r Warning : interrupt`vector[x]'s default is not defined near line 213 (test.cfg)
The interrupt vector of vector number x in the configuration file is not defined in the default configuration file.

cfg32r Warning : Initial Start Task not defined
The task of task ID number 1 was defined as the initial startup task because no initial startup task is defined in the configuration file.

Other messages

The following message are a warning message that is output only when generating makefile.The configurator skips the sections that have caused such a warning as it generates makefile.

test.c(line 11): include format error.
The file read format is incorrect. Rewrite it to the correct format.

cfg32r Warning : test.c(line 12): can't find <XXXX>

cfg32r Warning : test.c(line 13): can't find "XXXX"
The include file XXXX cannot be found. Check the file name and whether the file actually exists.

Chapter 8 How to Customize

8.1 Interruption Control Program

In MR32R, the portion related to a setup of the ICU or a setup of a timer is not contained in OS kernel, as “Figure 6.2 The procedure for running the interrupt handler“ shows.
About these setup, it carries out by the "ipl.ms (or ipl.s)" file. In MR32R, as there is "6.8.2 Automatic system clock settings", there is a template corresponding to some microcomputers, and the template can be used.
However, when there is no template corresponding to the microcomputer currently used, a user needs to create a "ipl.ms (or ipl.s)" file.

8.1.1 By the contents interruption processing

The program of processing of an interruption control program, it is a table. The assembler routine of the label shown in “Table 8.1 The functions needed in "ipl.ms"” is described. It explains below what processing each assembler routine needs to describe.

Table 8.1The functions needed in "ipl.ms"

Label	Outline	Register assurance
__sys_timer_init	|nitializes the timer.	Unnecessary
__SAVE_IPL_to_STACK	Saves an interrupt level int stack.	Necessary
__RESTORE_IPL_from_STACK	Restores an interrupt level from the stack.	Necessary
__set_ipl	Sets an interrupt priority level at the time of startup.	Unnecessary
__Int_Dummy	A dummy interrupt routine.	Necessary
__SYS_DUMMY	A dummy system call routine	Unnecessary

- **__sys_timer_init**
  This routine is called within a start-up routine, and performs setup of system time, and initialization of a system clock interruption. It is not dependent on a microcomputer, and the setting portion of system time is described like the portion of (1) in the sample program from the following paragraph. It is described that interruption generates initialization of a timer at arbitrary intervals according to the timer to use.
  In case a user describes timer initialization, “OTHER” is specified to be item "timer" of a system clock definition of a configuration file. At that time, the value specified to be "timer_clock", "IPL", "file_name", and "unit_time" is disregarded.

- **__SAVE_IPL_to_STACK**
  The entry address and the interruption status is saved on the stack area like “Figure 8.1 The stack status of interrupt control program” and it returns to OS processing. This routine is called from OS interruption entry processing shown by a figure “Figure 6.2 The procedure for running the interrupt handler” when interruption occurs.
  The entry address of an interrupt handler is read from the address table outputted by the configurator.
  The preparation of the address table is carried out from the interruption factor 0 to the value of the interruption factor which was specified by max_int of the maximum item definition of a configuration file in the INTERRUPT_VECTOR or the .INTERRUPT_VECTOR section (the head label is defined by __INT_VECTOR.).
  For example, when "max_int = 63;" is specified, the area of 64 is prepared from the interruption factor number 0 to the factor number 63.
  Moreover, the entry address of the interrupt handler corresponding to the item of an interrupt factor number in interrupt handler definition of a configuration file is outputted.
  For example, when it is specified as "interrupt_vector[16] =__sys_timer;", the label of __sys_timer is embedded for the entry of the interruption factor number 16. Therefore, the entry address of the interrupt handler corresponding to a factor number can be acquired by

reading __INT_VECTOR [an interruption factor number].

- **__RESTORE_IPL_from_STACK**
  The interruption status saved on the stack is restored, and it returns to OS processing shown as “Figure 8.1 The stack status of interrupt control program”. This routine is called from OS interruption entry processing shown by “Figure 5.8 Example of interrupt handler” when interruption occurs.

- **__set_ipl**
  An interruption mask level is set up. This routine is called from a start-up routine.

- **__Int_Dummy**[67]
  This routine is called when interruption which is not registered as an interrupt handler occurs.

- **__SYS_DUMMY**
  This routine is called when the system call defined as not using it by system call definition of a configuration file is used.

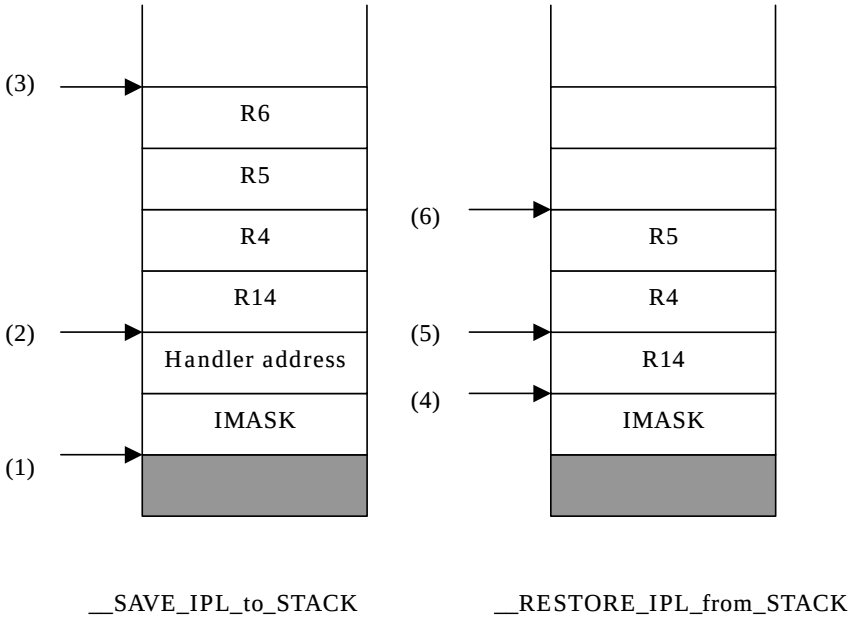


Figure 8.1 The stack status of interrupt control program

[67] As for interruption of the interruption factor number which is not registered as an interrupt handler, __Int_Dummy is embedded on an interrupt handler address table.

8.1.2 Interrupt Control Program(for CC32R)

```
 1 ;***************************************************************************
 2 ;
 3 ;   Copyright 2001 MITSUBISHI ELECTRIC CORPORATION
 4 ;   and MITSUBISHI ELECTRIC SEMICONDUCTOR APPLICATION ENGINEERING CORPORATION
 5 ;   All Rights Reserved.
 6 ;
 7 ;   $Id: ipl.ms,v 1.2 2001/04/18 06:24:29 inui Exp $
 8 ;
 9 ;***************************************************************************
10
11      .include        "mr32r.inc"
12      .section        MR_KERNEL,code
13
14 ICUISTS:     .equ    0x00EFF004
15 ICUIMASK:    .equ    0x00EFF01C
16 MFTCR:               .equ    0x00EFC000
17 MFTMOD:              .equ    0x00EFC100
18 MFTRLD:              .equ    0x00EFC10C
19 ICUCR:               .equ    0x00EFF23C
20 __write_bit: .equ    0x8000
21 __ena_bit:   .equ    0x0080
22 __timer_div: .equ    0x3
23 __timer_count:       .equ    0x6596
24
25      .global __sys_timer_init,__stmr_ipl,__stmr_src,__stmr_cnt
26      .global __D_Sys_TIME_H,__Sys_time,__stmr_ctr
27      .global __D_Sys_TIME_L
28
29
30 ;Use the label __sys_timer_init.
31 ;__sys_timer_init to initialize the timer is called from the startup routine
32 ;at the time when the timer is used.
33
34      .AIF    &¥USE_TIMER
35 __sys_timer_init:
36
37 ;Initialize the system time. Please do not change this portion.
38      st      r14,@-r15                       ┐
39      ld24    r4,#__D_Sys_TIME_H              │
40      lduh    r5,@r4                          │
41      ld24    r6,#__Sys_time                  │
42      sth     r5,@r6                          │
43      ld24    r4,#__D_Sys_TIME_L              │ (1)
44      ld      r5,@r4                          │
45      st      r5,@(2,r6)                      ┘
46
47 ;The initial cofiguration of the timer used for the system clock of OS is
48 ;performed.
49
50 ;MFT         control register setting
51      seth    r1,#shigh(MFTCR)
52      ld      r0,@(low(MFTCR),r1)
53      ld24    r2,#__write_bit
54      or      r0,r2
55      st      r0,@(low(MFTCR),r1)
56 ;MFT mode register setting
57      seth    r1,#shigh(MFTMOD)
58      ld24    r0,#0x8000
59      or3     r0,r0,#__timer_div
60      st      r0,@(low(MFTMOD),r1)
61 ;MFT reload register setting
62      seth    r1,#shigh(MFTRLD)
```

```
 63     ld24    r0,#__timer_count
 64     st      r0,@(low(MFTRLD),r1)
 65
 66 ;MFT interrupt control register setting(IEN=1, ILEVEL=3)
 67     seth    r1,#shigh(ICUCR)
 68     ldi     r0,#0x1100
 69     or3     r0,r0,#3
 70     st      r0,@(low(ICUCR),r1)
 71
 72 ;MFT control register setting
 73     seth    r1,#shigh(MFTCR)
 74     ld      r0,@(low(MFTCR),r1)
 75     ld24    r2,#(__write_bit | __ena_bit)
 76     or      r0,r2
 77     st      r0,@(low(MFTCR),r1)
 78
 79     ld      r14,@r15+
 80     jmp     r14
 81     .aendi
 82
 83 ; An interruption control register is saved, the jump place address of
 84 ;interruption is saved on a stack, and it returns to OS kernel.
 85 ; Since it is called from OS kernel by interruption entry processing,
 86 ; please do not change this label name.
 87 ;
 88     .global __SAVE_IPL_to_STACK,__INT_VECTOR
 89  __SAVE_IPL_to_STACK:
 90
 91 ; An interruption control register is saved on a stack and an interruption
 92 ;factor number is read.
 93     addi    r15,#-8                                 ------------(1)
 94     st      r14,@-r15                               ------------(2)
 95     st      r4,@-r15
 96     st      r5,@-r15
 97     st      r6,@-r15
 98     seth    r4,#shigh(ICUISTS) )                    ------------(3)
 99     ld      r5,@(low(ICUISTS),r4)
100     st      r5,@(D'20,r15)
101     srli    r5,#20
102
103 ;Table reference is carried out from __INT_VECTOR and interruption jump place
104 ; address is saved on a stack. This table is outputted to a sys_rom.inc file
105 ;by configurator as an INTERRUPT_VECTOR section, and can be arranged to
106 ;arbitrary addresses by it.
107
108     ld24    r6,#__INT_VECTOR
109     add     r6,r5
110     ld      r6,@r6
111     st      r6,@(16,r15)                            ------------(3)
112     ld      r6,@r15+
113     ld      r5,@r15+
114     ld      r4,@r15+
115     ld      r14,@r15+
116     jmp     r14                                     ------------(2)
117
118 ;An interruption control register is returned and it returns to OS kernel.
119 ;Since it is called from OS kernel by interruption exit processing,
120 ;please do not change this label name.
121     .global __RESTORE_IPL_from_STACK
122 __RESTORE_IPL_from_STACK:                           ------------(5)
123     st      r14,@-r15
124     st      r4,@-r15
125     st      r5,@-r15
126     ld      r5,@(12,r15)                            ------------(6)
```

```
127     seth    r4,#shigh(ICUIMASK)
128     st      r5,@(low(ICUIMASK),r4)
129     ld      r5,@r15+
130     ld      r4,@r15+
131     ld      r14,@r15+                                   ------------(5)
132     addi    r15,#4
133     jmp     r14                                         ------------(4)
134
135 ;The initial cofiguration of an interruption priority level is performed.
136 ;It is called from a start-up file.
137     .global __set_ipl
138 __set_ipl:
139     ldi     r5,#0x07
140     seth    r4,#shigh(ICUIMASK)
141     sth     r5,@(low(ICUIMASK),r4)
142     jmp     r14
143
144 ;It is the interruption routine of a dummy.
145 ;This routine is called when interruption which is not defined as an
146 ;interrupt handler in a configuration file occures.
147
148     .global __Int_Dummy
149 __Int_Dummy:
150     jmp     r14
151
152 ; This routine is called, when the system call is used in a user program,
153 ;in spite of having specified "NO" by the system call definition of a
154 ;configuration file.
155
156     .global __SYS_DUMMY
157 __SYS_DUMMY
158     jmp     r14
159
```

8.1.3 Interrupt Control Program(for TW32R)

```
 1 ;***************************************************************************
 2 ;
 3 ;   Copyright 2001 MITSUBISHI ELECTRIC CORPORATION
 4 ;   and MITSUBISHI ELECTRIC SEMICONDUCTOR APPLICATION ENGINEERING CORPORATION
 5 ;   All Rights Reserved.
 6 ;
 7 ;   $Id: ipl.s,v 1.3 2001/04/18 06:24:32 inui Exp $
 8 ;
 9 ;***************************************************************************
10
11
12      .include        "mr32r.inc"
13      .section        .MR_KERNEL,"ax"
14
15      .equ    ICUISTS,        0x00F7F004
16      .equ    ICUIMASK,       0x00F7F01C
17      .equ    MFTCR,          0x00F7C000
18      .equ    MFTMOD,         0x00F7C080
19      .equ    MFTOS,          0x00F7C088
20      .equ    MFTRLD,         0x00F7C08C
21      .equ    ICUCR,          0x00F7F23C
22      .equ    __write_bit,    0x8000
23      .equ    __ena_bit,      0x0080
24
25      .equ    __timer_count,  0x6596
26      .equ    __timer_div,    0x3
27
28 ;Use the label __sys_timer_init.
29 ;__sys_timer_init to initialize the timer is called from the startup routine
30 ;at the time when the timer is used.
31 .ifdef      USE_TIMER
32      .global __sys_timer_init,__stmr_ipl,__stmr_src,__stmr_cnt
33      .global __D_Sys_TIME_H,__Sys_time,__stmr_ctr
34
35 __sys_timer_init:
36
37 ;Initialize the system time. Please do not change this portion.
38      st      R14,@-R15                       ┐
39      ld24    R4,#__D_Sys_TIME_H              │
40      ldh     R5,@R4                          │
41      ld24    R6,#__Sys_time                  │
42      sth     R5,@R6                          │
43      ld24    R4,#__D_Sys_TIME_L              │ (1)
44      ld      R5,@R4                          │
45      st      R5,@(2,R6)                      ┘
46
47 ;The initial cofiguration of the timer used for the system clock of OS is
48 ;performed.
49
50      ld24    R10,#__timer_count
51      ldi     R12,#__timer_div
52 ;MFT         control register setting
53      ld24    r1,#MFTCR
54      ld      r0,@r1
55      ld24    r2,#__write_bit
56      or      r0,r2
57      st      r0,@r1
58 ;MFT mode register setting
59      ld24    r1,#MFTMOD
60      ld24    r0,#0x8000
61      or      r0,r12
62      st      r0,@r1
```

```
 63 ;MFT port output status register setting
 64      ld24    r1,MFTOS
 65      ldi     r0,#0
 66      st      r0,@r1
 67 ;MFT reload register setting
 68      ld24    r1,#MFTRLD
 69      addi    r10,#-1
 70      st      r10,@r1
 71
 72 ;MFT interrupt control register setting(IEN=1, ILEVEL=3)
 73      ld24    r1,#ICUCR
 74      ldi     r0,#0x1100
 75      or3     r0,r0,#__stmr_ipl
 76      st      r0,@r1
 77
 78 ;MFT control register setting
 79      ld24    r1,#MFTCR
 80      ld24    r2,#(__write_bit | __ena_bit)
 81      or      r0,r2
 82      st      r0,@r1
 83
 84      ld      r14,@r15+
 85      jmp     r14
 86      .endif
 87
 88 ; An interruption control register is saved, the jump place address of
 89 ;interruption is saved on a stack, and it returns to OS kernel.
 90 ; Since it is called from OS kernel by interruption entry processing,
 91 ; please do not change this label name.
 92 ;
 93
 94      .global __SAVE_IPL_to_STACK,__INT_VECTOR
 95  __SAVE_IPL_to_STACK:                                  ------------(1)
 96      addi    R15,#-8                                   ------------(2)
 97      st      R14,@-R15
 98      st      R4,@-R15
 99      st      R5,@-R15
100      st      R6,@-R15
101
102 ; An interruption control register is saved on a stack and an interruption
103 ;factor number is read.
104
105      ld24    r4,#ICUISTS                               ------------(3)
106      ld      r5,@r4
107      st      r5,@(20,r15)
108      srli    r5,#20
109
110 ;Table reference is carried out from __INT_VECTOR and interruption jump place
111 ; address is saved on a stack. This table is outputted to a sys_rom.inc file
112 ;by configurator as an INTERRUPT_VECTOR section, and can be arranged to
113 ;arbitrary addresses by it.
114
115      ld24    r6,#__INT_VECTOR
116      add     r6,r5
117      ld      r6,@r6
118      st      r6,@(16,r15)
119      ld      r6,@r15+                                  ------------(3)
120      ld      r5,@r15+
121      ld      r4,@r15+
122      ld      r14,@r15+
123      jmp     r14                                       ------------(2)
124
125 ;An interruption control register is returned and it returns to OS kernel.
126 ;Since it is called from OS kernel by interruption exit processing,
127 ;please do not change this label name.
```

```
128
129     .global __RESTORE_IPL_from_STACK
130 __RESTORE_IPL_from_STACK:                          ------------(5)
131     st      r14,@-r15
132     st      r4,@-r15
133     st      r5,@-r15
134     ld      r5,@(12,r15)                           ------------(6)
135     ld24    r4,#ICUIMASK
136     st      r5,@r4
137     ld      r5,@r15+                               ------------(5)
138     ld      r4,@r15+
139     ld      r14,@r15+
140     addi    r15,#4
141     jmp     r14                                    ------------(4)
142
143 ;The initial cofiguration of an interruption priority level is performed.
144 ;It is called from a start-up file.
145     .global __set_ipl
146 __set_ipl:
147     ldi     r5,#0x07
148     ld24    r4,#ICUIMASK
149     sth     r5,@r4
150     jmp     r14
151
152 ;It is the interruption routine of a dummy.
153 ;This routine is called when interruption which is not defined as an
154 ;interrupt handler in a configuration file occures.
155
156     .global __Int_Dummy
157 __Int_Dummy:
158     jmp     R14
159
160 ; This routine is called, when the system call is used in a user program,
161 ;in spite of having specified "NO" by the system call definition of a
162 ;configuration file.
163
164     .global __SYS_DUMMY
165 __SYS_DUMMY
166     jmp     r14
167
```

8.1.4 Interrupt Control Program(for DCC/M32R)

```
 1 ;***************************************************************************
 2 ;
 3 ;   Copyright 2001 MITSUBISHI ELECTRIC CORPORATION
 4 ;   and MITSUBISHI ELECTRIC SEMICONDUCTOR APPLICATION ENGINEERING CORPORATION
 5 ;   All Rights Reserved.
 6 ;
 7 ;   $Id: ipl.s,v 1.3 2001/04/18 06:24:30 inui Exp $
 8 ;
 9 ;***************************************************************************
10
11     .include        "mr32r.inc"
12     .section        .MR_KERNEL,"ax"
13
14     .equ    ICUISTS,        0x00F7F004
15     .equ    ICUIMASK,       0x00F7F01C
16     .equ    MFTCR,          0x00F7C000
17     .equ    MFTMOD,         0x00F7C080
18     .equ    MFTOS,          0x00F7C088
19     .equ    MFTRLD,         0x00F7C08C
20     .equ    ICUCR,          0x00F7F23C
21     .equ    __write_bit,    0x8000
22     .equ    __ena_bit,      0x0080
23
24     .equ    __timer_count,  0x6596
25     .equ    __timer_div,    0x3
26
27 ;Use the label __sys_timer_init.
28 ;__sys_timer_init to initialize the timer is called from the startup routine
29 ;at the time when the timer is used.
30 .ifdef      USE_TIMER
31     .global __sys_timer_init,__stmr_ipl,__stmr_src,__stmr_cnt
32     .global __D_Sys_TIME_H,__Sys_time,__stmr_ctr
33
34 __sys_timer_init:
35
36 ;Initialize the system time. Please do not change this portion.
37
38     st      R14,@-R15                   ┐
39     ld24    R4,#__D_Sys_TIME_H          │
40     ldh     R5,@R4                      │
41     ld24    R6,#__Sys_time              │
42     sth     R5,@R6                      │ (1)
43     ld24    R4,#__D_Sys_TIME_L          │
44     ld      R5,@R4                      │
45     st      R5,@(2,R6)                  ┘
46
47 ;The initial cofiguration of the timer used for the system clock of OS is
48 ;performed.
49
50     ld24    R10,#__timer_count
51     ldi     R12,#__timer_div
52 ;MFT        control register setting
53     ld24    r1,#MFTCR
54     ld      r0,@r1
55     ld24    r2,#__write_bit
56     or      r0,r2
57     st      r0,@r1
58 ;MFT mode register setting
59     ld24    r1,#MFTMOD
60     ld24    r0,#0x8000
61     or      r0,r12
62     st      r0,@r1
```

```
 63 ;MFT port output status register setting
 64      ld24    r1,MFTOS
 65      ldi     r0,#0
 66      st      r0,@r1
 67 ;MFT reload register setting
 68      ld24    r1,#MFTRLD
 69      addi    r10,#-1
 70      st      r10,@r1
 71
 72 ;MFT interrupt control register setting(IEN=1, ILEVEL=3)
 73      ld24    r1,#ICUCR
 74      ldi     r0,#0x1100
 75      or3     r0,r0,#__stmr_ipl
 76      st      r0,@r1
 77
 78 ;MFT control register setting
 79      ld24    r1,#MFTCR
 80      ld24    r2,#(__write_bit | __ena_bit)
 81      or      r0,r2
 82      st      r0,@r1
 83
 84      ld      r14,@r15+
 85      jmp     r14
 86      .endif
 87
 88 ; An interruption control register is saved, the jump place address of
 89 ;interruption is saved on a stack, and it returns to OS kernel.
 90 ; Since it is called from OS kernel by interruption entry processing,
 91 ; please do not change this label name.
 92 ;
 93
 94      .global __SAVE_IPL_to_STACK,__INT_VECTOR
 95  __SAVE_IPL_to_STACK:                                  ------------(1)
 96      addi    R15,#-8                                   ------------(2)
 97      st      R14,@-R15
 98      st      R4,@-R15
 99      st      R5,@-R15
100      st      R6,@-R15
101
102 ; An interruption control register is saved on a stack and an interruption
103 ;factor number is read.
104
105      ld24    r4,#ICUISTS                               ------------(3)
106      ld      r5,@r4
107      st      r5,@(20,r15)
108      srli    r5,#20
109
110 ;Table reference is carried out from __INT_VECTOR and interruption jump place
111 ; address is saved on a stack. This table is outputted to a sys_rom.inc file
112 ;by configurator as an INTERRUPT_VECTOR section, and can be arranged to
113 ;arbitrary addresses by it.
114
115      ld24    r6,#__INT_VECTOR
116      add     r6,r5
117      ld      r6,@r6
118      st      r6,@(16,r15)
119      ld      R6,@R15+                                  ------------(3)
120      ld      R5,@R15+
121      ld      R4,@R15+
122      ld      R14,@R15+
123      jmp     R14                                       ------------(2)
124
125 ;An interruption control register is returned and it returns to OS kernel.
126 ;Since it is called from OS kernel by interruption exit processing,
```

```
127 ;please do not change this label name.
128
129     .global __RESTORE_IPL_from_STACK
130 __RESTORE_IPL_from_STACK:                          ------------(5)
131     st      R14,@-R15
132     st      R4,@-R15
133     st      R5,@-R15
134     ld      R5,@(12,R15)                           ------------(6)
135     ld24    r4,#ICUIMASK
136     st      r5,@r4
137     ld      R5,@R15+
138     ld      R4,@R15+
139     ld      R14,@R15+                              ------------(5)
140     addi    R15,#4
141     jmp     R14                                    ------------(4)
142
143 ;The initial cofiguration of an interruption priority level is performed.
144 ;It is called from a start-up file.
145
146     .global __set_ipl
147 __set_ipl:
148     ldi     r5,#0x07
149     ld24    r4,#ICUIMASK
150     sth     r5,@r4
151     jmp     r14
152
153 ;It is the interruption routine of a dummy.
154 ;This routine is called when interruption which is not defined as an
155 ;interrupt handler in a configuration file occures.
156
157     .global __Int_Dummy
158 __Int_Dummy:
159     jmp     R14
160
161 ; This routine is called, when the system call is used in a user program,
162 ;in spite of having specified "NO" by the system call definition of a
163 ;configuration file.
164
165     .global __SYS_DUMMY
166 __SYS_DUMMY
167     jmp     r14
168
```

8.2 How to Customize the MR32R Startup Program

The MR32R is provided with two startup programs as given below.

- start.ms (start.s for TW32R or D-CC/M32R)
  This is a startup program to use if you write a program in assembly language.

- crt0mr.ms (crt0mr.s for TW32R or D-CC/M32R)
  This is a startup program to use if you write a program in C A program resulting from adding a C-written initialization routine to start.ms.

The startup program process such as below.

- Setting a stack pointer
- Initializing the processor after resetting
- Transferring the data to the built-in DRAM from an external ROM such as an EIT vector entry, a program area, or the like.
- Initializing variables in C-written programs (crt0mr.ms,crt0mr.s only)
- Setting the system timer
- Initializing the MR32R's data areas.

Copy these start up programs to the current directory from the directory that the environment variable "LIB32R" points at. If necessary, modify or add the startup file.[68]

[68] With the startup program absent from the current directory, executing the configurator taking in the optionm copies the startup program to the current directory from the directory that the environment variable LIB32R points at.

8.2.1 Transferring the data to the built-in DRAM from an external

In MR32R, a "DOWNLOAD" macro which is defined by the file “mr32r.inc” can be used, and transmission processing to RAM from ROM can be performed. By the start-up routine of product appending, transmission processing of the data area with initilal value and the MR_ROM (or .MR_ROM) section is performed. The following paragraph explains the change method and the description method of the section file (section, m32r.cmd) at the time of using the macro for download.

- **With CC32R in use**

DOWNLOAD reg1,reg2,reg3,section,ROM_section

Specify registers to be used in the macro for reg1,reg2,reg3. Specify for section a section name to be downloaded, and specify for ROM_section a name that precedes with ROM_ the section name specified for the aforesaid section.
A macro description to transfer the PROGRAM section using registers R0,R1,R2,R3 is given here.[69]

DOWNLOAD R0,R1,R2,R3,DATA,ROM_DATA

- **With TW32R in use**

DOWNLOAD
reg1,reg2,reg3,reg4,start_section,end_section,rom_section

Specify registers to be used in the macro for reg1,reg2,reg3,reg4.
Specify for start_section the first address of the downloading target, specify for end_section the tail address of the downloading target, and specify for rom_section the first address of the downloading source.
Usually, symbols set in the linker script file m32r.cmd are used for these addresses.
Here is a macro to transfer the .text area described as shown below in `m32r.cmd' by use of registers R0,R1,R2,R3.

```
.data (ADDR(.MR_RAM)+SIZEOF(.MR_RAM)) : AT( LOADADDR(.rodata) + SIZEOF(.rodata) )
{
  __data_start = .;
  *(.data)
  *(.gnu.linkonce.d*)
  CONSTRUCTORS
  __data_end = .;
}
__rom_data = LOADADDR(.data);
```

DOWNLOAD R0,R1,R2,R3,__data_start,__data_end,__rom_data

[69] In this instance, the ROM_PROGRAM section is automatically generated By the linker, and the section needs to be defined in the startup file.

- **With D-CC/M32R in use**

DOWNLOAD reg1,reg2,reg3,reg4,start_section,end_section,rom_section

Specify registers to be used in the macro for reg1,reg2,reg3,reg4.
Specify for start_section the first address of the downloading target, specify for end_section the tail address of the downloading target, and specify for rom_section the first address of the downloading source.
Usually, symbols set in the linker script file m32r.cmd are used for these addresses.
Here is a macro to transfer the .text area described as shown below in `m32r.cmd' by use of registers R0,R1,R2,R3.

```
__START_data = .;
  .data LOAD(__ROM_data): {
    *(.data)
  }
  __END_data = .;

   DOWNLOAD   R0,R1,R2,R3,__START_data,__END_data,__ROM_data
```

8.2.2 How to Stop Transmission to RAM from ROM

The section without the necessity of transmitting to RAM from ROM cancels transmission processing. The section with the necessity of transmitting, and the section without the necessity of transmitting are as follows.

Section which is needed to be transferred ROM area to RAM area

- **D(.sdata,.data)** **Data section with initial value**

Section which is not needed to be transferred ROM area to RAM area

- **P(.text)** **User program section**
- **C(.rodata)** **Constant data section**
- **MR_KERNEL(.MR_KERNEL)** **OS kernel section**

Transferring depends on the condition

- **MR_ROM(.MR_ROM)** **OS data section**
  If you use dynamic task creation or OS object creation function,it need to transfer ROM area to RAM area.
- **INTERRUPT_VECTOR(.INTERRUPT_VECTOR)** **Interrupt vector table section**
  You must delete transferring process description in start-up program if you must allocate this section on ROM(Flash ROM) area.
- **EIT_Vector(.EIT_Vector)** **EIT vector section**
  You must delete transferring process description in start-up program if you must allocate this section on ROM(Flash ROM) area.
- **Int_Vector(.Int_Vector)** **Interrupt vector section**
  You must delete transferring process description in start-up program if you must allocate this section on ROM(Flash ROM) area.

Below is the procedure of cancel of transferring process.

1. Delete needless section in start-up program if using CC32R.
   (The sectios to be deleted are the sections added “ROM_” letters to these section name;ROM_P, ROM_C, etc.)
2. Delete “DOWNLOAD” MACROS of the section which is not transferred in start-up program.
3. Modify section file(section) or linker script(m32r.cmd).
   (See the cross tool manual how to modify section file or linker script.)

8.2.3 Startup Program for C Language(for CC32R)(crt0mr.ms)

```
 1 ;*****************************************************************************
 2 ;
 3 ;   MR32R start up program for C language (for CC32R)
 4 ;   Copyright 2001 MITSUBISHI ELECTRIC CORPORATION
 5 ;   and MITSUBISHI ELECTRIC SEMICONDUCTOR APPLICATION ENGINEERING CORPORATION
 6 ;   All Rights Reserved.
 7 ;
 8 ; $Id: crt0mr.ms,v 1.5 2001/04/23 07:05:17 inui Exp $
 9 ;
10 ;*****************************************************************************
11
12 ; A file required to incorporate OS is included.
13 ; Please do not change this portion.
14
15      .include        "mr32r.inc"
16      .include        "sys_rom.inc"
17      .include        "sys_ram.inc"
18      .include        "mrtable.inc"
19
20      .global         __Sys_Sp,__sys_timer,__int_entry,__START
21      .global         __D_INIT_START,__sys_timer_init,__start_up_exit
22      .global         __TOP_USER_STACK,$_init_usr_memblk,$usr_getmem
23      .global         __SYSCALL0,__SYSCALL1,__TOP_HEAP,$_init_memblk
24      .global         __set_ipl
25      .section        B,data
26      .section        D,data
27      .section        P,code
28      .section        C,data
29      .section        ROM_D,data
30      .section        ROM_INTERRUPT_VECTOR,data
31      .section        INTERRUPT_VECTOR,data
32      .section        MR_HEAP,data,align=4
33      .section        EXT_MR_HEAP,data,align=4
34      .section        INT_USR_STACK,data,align=4
35      .section        EXT_USR_STACK,data,align=4
36      .section        EXT_MR_RAM,data,align=4
37      .section        MR_KERNEL2,code,align=4
38      .section        MR_KERNEL,code,align=4
39      .section        ROM_MR_ROM,data,align=4
40      .section        MR_ROM,data,align=4
41      .section        OS_DEBUG,code,align=4
42
43 ; a section definition of a start-up file
44
45      .section        START_UP,code,align=4
46 NULL:        .EQU    0
47
48 ; When you use the base register function, please set value as each symbol.
49 ; When not using a base register function, it is necessary to set up value
50 ; with a dummy also about the register not to use.
51
52      .global __REL_BASE11
53      .global __REL_BASE12
54      .global __REL_BASE13
55      .global __REL_BASE
56 __REL_BASE11:        .equ    0
57 __REL_BASE12:        .equ    0
58 __REL_BASE:  .equ    0
59 __REL_BASE13:        .equ    __REL_BASE
60
61 ; A start-up program is started from here.
62
```

```
 63 __START:
 64
 65 ; A system stack pointer is set up.
 66
 67     seth    r1,#high(__Sys_Sp)
 68     or3     r1,r1,#low(__Sys_Sp)
 69     addi    r1,#-4
 70     mvtc    r1,SPI              ;SPI initialize
 71     mvtc    r1,SPU
 72     ldi     r0,#-1
 73     st      r0,@r1
 74     ldi     r0,#NULL
 75     mvtc    r0,PSW              ;PSW initialize
 76
 77 ; When a base register function is used and when calling the function
 78 ; written in C language from the start-up routine, R11-R13 registers must be
 79 ; set up.
 80
 81 ;    seth    R11,#high(__REL_BASE11)
 82 ;    or3     R11,R11,#low(__REL_BASE11)
 83 ;    seth    R12,#high(__REL_BASE12)
 84 ;    or3     R12,R12,#low(__REL_BASE12)
 85 ;    seth    R13,#high(__REL_BASE13)
 86 ;    or3     R13,R13,#low(__REL_BASE13)
 87
 88     .AIF    ¥&__Dbg_flg gt 0
 89     ld24    r1,#__Dbg_mode
 90 ;    ldi     r2,#0
 91     ldi     r2,#4
 92     stb     r2,@r1
 93     .AENDI
 94
 95 ; Perform a setup in the mode of a microcomputer of operation etc.
 96 ;
 97 ;    Description below,if you need
 98 ;    (ex. Master/Slavemode initialize,Power management initialize)
 99 ;
100
101 ; The zero clearance of the data without initial value is carried out.
102 ; This macro is defined by "mr32r.inc" and a user can also use it freely.
103
104     RAM_CLEAR r0,r1,r2,B
105
106 ; It transmits to a built-in RAM area from an external ROM area.
107 ; A user can also use this broad view freely.
108
109     DOWNLOAD r0,r1,r2,r3,D,ROM_D
110
111 ; The standard library of the C language is initialized.
112 ;
113
114 ;Initialize standard library
115 ;
116
117 ;    .global __init_mem,__init_stdio
118 ;    bl      __init_mem
119 ;    bl      __init_stdio
120
121     .global __OS_INIT
122
123 ; OS is initialized.
124 __OS_INIT:
125
126     DOWNLOAD r0,r1,r2,r3,MR_ROM,ROM_MR_ROM
127     DOWNLOAD r0,r1,r2,r3,INTERRUPT_VECTOR,ROM_INTERRUPT_VECTOR
```

```
128 ;
129 ;Initialize OS system area
130 ;
131
132     INITIALIZE
133
134 ; The initialization fot the OS debugging function is performed.
135
136     .AIF    ¥&__Dbg_flg gt 0
137     ld24    r1,#__Dbg_buffer_start
138     ld24    r0,#__Dbg_addr
139     st      r1,@r0
140     ld24    r1,#__Dbg_cnt
141     ldi     r0,#0
142     st      r0,@r1
143     ld24    r1,#__Dbg_mode
144     ldb     r0,@r1
145     ldi     r2,#1
146     or      r0,r2
147     stb     r0,@r1
148     .aendi
149
150 ; __set_ipl in 'ipl.ms' is called and the initial cofiguration of an
151 ; interrupt priority level is performed.
152
153     bl      __set_ipl
154
155 ; When using a timer, __sys_timer_init in 'ipl.ms' is called and the
156 ; initialization for the timer is performed.
157
158     .AIF    ¥&USE_TIMER gt 0
159     bl      __sys_timer_init
160     .AENDI
161
162 ;    .global __init_abort
163 ;    bl      __init_abort
164     ldi     r4,#2
165
166 ;
167 ;Start task
168 ;
169
170 ; An initial starting task is started.
171 ; Please do not change this portion.
172
173 start_task:
174     ld24    r5,#__D_INIT_START-2
175     add     r5,r4
176     lduh    r1,@r5
177     beqz    r1,start_task_end
178     ldi     r2,#NULL
179     ldi     r0,#ISTA_TSK
180     TRAP    #8
181     addi    r4,#2
182     bra     start_task
183
184 start_task_end:
185     ldi     r5,#NULL
186     ld24    r4,#__enq_dsp
187     stb     r5,@r4
188     bra     __start_up_exit
189
190 ; Please do not change this portion.
191
```

```
192     .AIF    ¥&__Dbg_flg eq 0
193     .section        MR_KERNEL,code,align=4
194     .align  4
195     .global __Dbg_idle
196     .global __Dbg_RUNtsk,__Dbg_int_entry,__Dbg_int_exit
197     .global __Dbg_ent_handler,__Dbg_ext_handler,__Dbg_int_exit2
198     .global __Dbg_sys_exit,__Dbg_sys_exit2,__Dbg_sys_timer
199 __Dbg_idle:
200 __Dbg_RUNtsk:
201 __Dbg_int_entry:
202 __Dbg_int_exit:
203 __Dbg_int_exit2:
204 __Dbg_ent_handler:
205 __Dbg_ext_handler:
206 __Dbg_sys_exit:
207 __Dbg_sys_exit2:
208 __Dbg_sys_timer:
209     .AENDI
210
211     .aif ¥&__MR_EXC_HANDLER
212     .global __DEF_EXC_HDR
213 __DEF_EXC_HDR:
214     vret_exc
215     .aendi
216
217     .AIF    ¥&__Dbg_flg gt 0
218     .section        MR_Dbg_RAM,data
219     .align  4
220     .global __Dbg_mode
221     .global __Dbg_buffer_start
222     .global __Dbg_buffer_end
223     .global __Dbg_cnt
224     .global __Dbg_addr
225     .global __Dbg_sys_iss
226 __Dbg_buffer_start:
227     .res.b  __Dbg_buffer_size
228 __Dbg_buffer_end:
229 __Dbg_addr:  .res.w  1
230 __Dbg_cnt:   .res.w  1
231 __Dbg_sys_iss:      .res.w  7
232 __Dbg_mode:  .res.b  1
233     .aelse
234     .section        MR_Dbg_RAM,data
235     .align  4
236     .global __Dbg_mode
237     .global __Dbg_buffer_start
238     .global __Dbg_buffer_end
239     .global __Dbg_cnt
240     .global __Dbg_addr
241     .global __Dbg_sys_iss
242 __Dbg_buffer_start:
243 __Dbg_buffer_end:
244 __Dbg_addr:
245 __Dbg_cnt:
246 __Dbg_mode:
247 __Dbg_sys_iss:
248     .aendi
249
250 ;***************  EIT Vector AREA  ********************
251
252 ; EIT vector area is set up.
253
254     .section        EIT_Vector,CODE,ALIGN=4
255     rte                             ;TRAP0
256     nop
```

```
257     rte                             ;TRAP1
258     nop
259     rte                             ;TRAP2
260     nop
261     rte                             ;TRAP3
262     nop
263     rte                             ;TRAP4
264     nop
265     rte                             ;TRAP5
266     nop
267     rte                             ;TRAP6
268     nop
269     .AIF    ¥&__Dbg_flg eq 0
270     bra     __SYSCALL0              ;TRAP7
271     bra     __SYSCALL1              ;TRAP8
272     .AELSE
273     .global __Dbg_entry0,__Dbg_entry1
274     bra     __Dbg_entry0            ;TRAP7
275     bra     __Dbg_entry1            ;TRAP8
276     .AENDI
277     rte                             ;TRAP9
278     nop
279     rte                             ;TRAP10
280     nop
281     rte                             ;TRAP11
282     nop
283     rte                             ;TRAP12
284     nop
285     rte                             ;TRAP13
286     nop
287 ;   rte                             ;TRAP14
288 ;   nop
289 ;   rte                             ;TRAP15
290 ;   nop
291     .section        Int_Vector,code,align=4
292     bra     __int_entry
293
294     .SECTION        RESET_VECT,code,align=4
295 ;   bra     __START
296
297     .end
```

Figure 8.2 Startup Program for C Language(for CC32R)

8.2.4 Startup Program for C Language(for TW32R)(crt0mr.s)

Figure 8.3 shows details about the startup program for C language(for TW32R).

```
 1 ;******************************************************************************
 2 ;
 3 ;   MR32R start up program for C language (for TW32R)
 4 ;   Copyright 2001 MITSUBISHI ELECTRIC CORPORATION
 5 ;   and MITSUBISHI ELECTRIC SEMICONDUCTOR APPLICATION ENGINEERING CORPORATION
 6 ;   All Rights Reserved.
 7 ;
 8 ; $Id: crt0mr.s,v 1.4 2001/04/23 07:05:18 inui Exp $
 9 ;
10 ;******************************************************************************
11
12 ; A file required to incorporate OS is included.
13 ; Please do not change this portion.
14
15      .include        "mr32r.inc"
16      .include        "sys_rom.inc"
17      .include        "sys_ram.inc"
18      .include        "mrtable.inc"
19
20      .global         __Sys_Sp,__sys_timer,__START
21      .global         __D_INIT_START,__sys_timer_init,__start_up_exit
22      .global         __TOP_USER_STACK,_init_usr_memblk,usr_getmem
23      .global         __SYSCALL0,__SYSCALL1,__TOP_HEAP,_init_memblk
24
25 ; a section definition of a start-up file
26
27      .section        .STARTUP,"awx"
28      .balign         4
29      .equ            NULL,0
30
31 ; A start-up program is started from here.
32
33 __START:
34
35 ; A system stack pointer is set up.
36
37      seth    r1,#high(__Sys_Sp)
38      or3     r1,r1,#low(__Sys_Sp)
39      addi    r1,#-4
40      mvtc    r1,CR2              ;SPI initialize
41      mvtc    r1,CR3
42      ldi     r0,#-1
43      st      r0,@r1
44      ldi     r0,#NULL
45      mvtc    r0,CR0              ;PSW initialize
46
47      .if     __Dbg_flg
48      ld24    r1,#__Dbg_mode
49 ;    ldi     r2,#0
50      ldi     r2,#4
51      stb     r2,@r1
52      .endif
53
54 ; Perform a setup in the mode of a microcomputer of operation etc.
55
56 ;
57 ;    Description below,if you need
58 ;    (ex. Master/Slavemode initialize,Power management initialize)
59 ;
60 ;
```

```
 61 ;    Initialize section
 62 ;
 63
 64 ; The zero clearance of the data without initial value is carried out.
 65 ; This macro is defined by "mr32r.inc" and a user can also use it freely.
 66
 67     RAM_CLEAR R0,R1,R2,__sbss_start,__sbss_end
 68     RAM_CLEAR R0,R1,R2,__bss_start,__bss_end
 69
 70
 71 ; It transmits to a built-in RAM area from an external ROM area.
 72 ; A user can also use this broad view freely.
 73
 74     DOWNLOAD  R0,R1,R2,R3,__mr_rom_start,__mr_rom_end,__rom_mr_rom
 75     DOWNLOAD  R0,R1,R2,R3,__data_start,__data_end,__rom_data
 76     DOWNLOAD  R0,R1,R2,R3,__sdata_start,__sdata_end,__rom_sdata
 77
 78 ; The standard library of the C language is initialized.
 79
 80 ;
 81 ;    initialize C language library
 82 ;
 83 ;    .global _init_mem,_init_stdio,__OS_INIT
 84 ;    bl      _init_mem
 85 ;    bl      _init_stdio
 86
 87 ; OS is initialized.
 88
 89 __OS_INIT:
 90 ;
 91 ;Initialize OS system area
 92 ;
 93     INITIALIZE
 94
 95 ; The initialization fot the OS debugging function is performed.
 96
 97     .if     __Dbg_flg
 98     ld24    r1,#__Dbg_buffer_start
 99     ld24    r0,#__Dbg_addr
100     st      r1,@r0
101     ld24    r1,#__Dbg_cnt
102     ldi     r0,#0
103     st      r0,@r1
104     ld24    r1,#__Dbg_mode
105     ldb     r0,@r1
106     ldi     r2,#1
107     or      r0,r2
108     stb     r0,@r1
109     .endif
110
111 ; __set_ipl in 'ipl.ms' is called and the initial cofiguration of an
112 ; interrupt priority level is performed.
113
114     bl      __set_ipl
115
116 ; When using a timer, __sys_timer_init in 'ipl.ms' is called and the
117 ; initialization for the timer is performed.
118
119     .ifdef  USE_TIMER
120     bl      __sys_timer_init
121     .endif
122
123 ;    bl      __init_abort
124
```

```
125 ;
126 ;Start task
127 ;
128
129 ; An initial starting task is started.
130 ; Please do not change this portion.
131
132     ldi     R4,#2
133 start_task:
134     ld24    R5,#__D_INIT_START
135     add     R5,R4
136     lduh    R1,@(-2,R5)
137     beqz    R1,start_task_end
138     ldi     R2,#NULL
139     ldi     R0,#ISTA_TSK
140     TRAP    #8
141     addi    R4,#2
142     bra     start_task
143 start_task_end:
144     ldi     R5,#NULL
145     ld24    R4,#__enq_dsp
146     stb     R5,@R4
147     bra     __start_up_exit
148
149 ; Please do not change this portion.
150
151     .if !(__Dbg_flg )
152     .section        .MR_KERNEL,"ax"
153     .align  4
154     .global __Dbg_idle
155     .global __Dbg_RUNtsk,__Dbg_int_entry,__Dbg_int_exit
156     .global __Dbg_ent_handler,__Dbg_ext_handler,__Dbg_int_exit2
157     .global __Dbg_sys_exit,__Dbg_sys_exit2,__Dbg_sys_timer
158 __Dbg_idle:
159 __Dbg_RUNtsk:
160 __Dbg_int_entry:
161 __Dbg_int_exit:
162 __Dbg_int_exit2:
163 __Dbg_ent_handler:
164 __Dbg_ext_handler:
165 __Dbg_sys_exit:
166 __Dbg_sys_exit2:
167 __Dbg_sys_timer:
168     .endif
169
170     .if     __Dbg_flg
171     .section        MR_Dbg_RAM,"aw"
172     .align  4
173     .global __Dbg_mode
174     .global __Dbg_buffer_start
175     .global __Dbg_buffer_end
176     .global __Dbg_cnt
177     .global __Dbg_addr
178 __Dbg_buffer_start:
179     .space  __Dbg_buffer_size
180 __Dbg_buffer_end:
181 __Dbg_addr:  .space  1*4
182 __Dbg_cnt:   .space  1*4
183 __Dbg_sys_iss:       .space  7*4
184 __Dbg_mode:  .space  1
185     .else
186     .section        .MR_Dbg_RAM,"aw"
187     .align  4
188     .global __Dbg_mode
189     .global __Dbg_buffer_start
```

```
190     .global __Dbg_buffer_end
191     .global __Dbg_cnt
192     .global __Dbg_addr
193     .global __Dbg_sys_iss
194 __Dbg_buffer_start:
195 __Dbg_buffer_end:
196 __Dbg_addr:
197 __Dbg_cnt:
198 __Dbg_mode:
199 __Dbg_sys_iss:
200     .endif
201 ;***************  EIT Vector AREA ***********************
202 ; EIT vector area is set up.
203
204     .section        .EIT_Vector,"awx"
205     .balign         4
206     rte                             ;TRAP0
207     nop
208     rte                             ;TRAP1
209     nop
210     rte                             ;TRAP2
211     nop
212     rte                             ;TRAP3
213     nop
214     rte                             ;TRAP4
215     nop
216     rte                             ;TRAP5
217     nop
218     rte                             ;TRAP6
219     nop
220     .if !(__Dbg_flg )
221     bra     __SYSCALL0              ;TRAP7
222     bra     __SYSCALL1              ;TRAP8
223     .else
224     .global  __Dbg_entry0,__Dbg_entry1
225     bra     __Dbg_entry0
226     bra     __Dbg_entry1
227     .endif
228     rte                             ;TRAP9
229     nop
230     rte                             ;TRAP10
231     nop
232     rte                             ;TRAP11
233     nop
234     rte                             ;TRAP12
235     nop
236     rte                             ;TRAP13
237     nop
238 ;   rte                             ;TRAP14
239 ;   nop
240 ;   rte                             ;TRAP15
241 ;   nop
242     .section        .Int_Vector,"awx"
243     .balign         4
244     .global __int_entry
245     bra     __int_entry
246
247 .if  __MR_EXC_HANDLER
248     .global __DEF_EXC_HDR
249 __DEF_EXC_HDR:
250     vret_exc
251 .endif
252
253 ;   .section        .RESET_VECT,"ax"
```

```
254 ;    .align          4
255 ;reset:
256 ;    bra     __START
257
```

Figure 8.3 Startup Program for C Language(for TW32R)

8.2.5 Startup Program for C Language(for DCC/M32R)(crt0mr.s)

```
 1 ;******************************************************************************
 2 ;
 3 ;   MR32R start up program for C language (for DCC/M32R)
 4 ;   Copyright 2001 MITSUBISHI ELECTRIC CORPORATION
 5 ;   and MITSUBISHI ELECTRIC SEMICONDUCTOR APPLICATION ENGINEERING CORPORATION
 6 ;   All Rights Reserved.
 7 ;
 8 ; $Id: crt0mr.s,v 1.3 2001/04/23 07:05:17 inui Exp $
 9 ;
10 ;******************************************************************************
11
12 ; A file required to incorporate OS is included.
13 ; Please do not change this portion.
14
15     .include        "mr32r.inc"
16     .include        "sys_rom.inc"
17     .include        "sys_ram.inc"
18     .include        "mrtable.inc"
19
20     .global         __Sys_Sp,__sys_timer,__START
21     .global         __D_INIT_START,__sys_timer_init,__start_up_exit
22     .global         __TOP_USER_STACK,_init_usr_memblk,usr_getmem
23     .global         __SYSCALL0,__SYSCALL1,__TOP_HEAP,_init_memblk
24
25 ; a section definition of a start-up file
26
27     .section        .STARTUP,"awx"
28     .balign         4
29     .equ            NULL,0
30
31 ; A start-up program is started from here.
32
33 __START:
34
35 ; A system stack pointer is set up.
36
37     seth    r1,#__Sys_Sp@h
38     or3     r1,r1,#__Sys_Sp@l
39     addi    r1,#-4
40     mvtc    r1,CR2              ;SPI initialize
41     mvtc    r1,CR3
42     ldi     r0,#-1
43     st      r0,@r1
44     ldi     r0,#NULL
45     mvtc    r0,CR0              ;PSW initialize
46
47     .if     __Dbg_flg
48     ld24    r1,#__Dbg_mode
49 ;   ldi     r2,#0
50     ldi     r2,#4
51     stb     r2,@r1
52     .endif
53
54 ; Perform a setup in the mode of a microcomputer of operation etc.
55
56 ;    Description below,if you need
57 ;    (ex. Master/Slavemode initialize,Power management initialize)
58 ;
59 ;    Initialize section
60 ;
61
62 ; The zero clearance of the data without initial value is carried out.
```

```
 63 ; This macro is defined by "mr32r.inc" and a user can also use it freely.
 64
 65     RAM_CLEAR R0,R1,R2,__START_bss,__END_bss
 66
 67 ; It transmits to a built-in RAM area from an external ROM area.
 68 ; A user can also use this broad view freely.
 69
 70     RAM_CLEAR R0,R1,R2,__START_bss,__END_bss
 71     DOWNLOAD  R0,R1,R2,R3,__START_MR_ROM,__END_MR_ROM,__ROM_MR_ROM
 72     DOWNLOAD  R0,R1,R2,R3,__START_data,__END_data,__ROM_data
 73
 74 ; The standard library of the C language is initialized.
 75
 76 ;
 77 ;    initialize C language library
 78 ;
 79
 80 ; OS is initialized.
 81
 82 __OS_INIT:
 83 ;
 84 ;Initialize OS system area
 85 ;
 86     INITIALIZE
 87
 88 ; The initialization fot the OS debugging function is performed.
 89
 90     .if     __Dbg_flg
 91     ld24    r1,#__Dbg_buffer_start
 92     ld24    r0,#__Dbg_addr
 93     st      r1,@r0
 94     ld24    r1,#__Dbg_cnt
 95     ldi     r0,#0
 96     st      r0,@r1
 97     ld24    r1,#__Dbg_mode
 98     ldb     r0,@r1
 99     ldi     r2,#1
100     or      r0,r2
101     stb     r0,@r1
102     .endif
103
104 ; __set_ipl in 'ipl.ms' is called and the initial cofiguration of an
105 ; interrupt priority level is performed.
106
107     bl      __set_ipl
108
109 ; When using a timer, __sys_timer_init in 'ipl.ms' is called and the
110 ; initialization for the timer is performed.
111
112     .ifdef  USE_TIMER
113     bl      __sys_timer_init
114     .endif
115
116 ;    bl      __init_abort
117
118 ;Start task
119
120 ; An initial starting task is started.
121 ; Please do not change this portion.
122
123     ldi     R4,#2
124 start_task:
125     ld24    R5,#__D_INIT_START
126     add     R5,R4
127     lduh    R1,@(-2,R5)
```

```
128     beqz    R1,start_task_end
129     ldi     R2,#NULL
130     ldi     R0,#ISTA_TSK
131     TRAP    #8
132     addi    R4,#2
133     bra     start_task
134 start_task_end:
135     ldi     R5,#NULL
136     ld24    R4,#__enq_dsp
137     stb     R5,@R4
138     bra     __start_up_exit
139
140     .global __init
141 __init:
142     jmp     r14
143
144 ; Please do not change this portion.
145
146     .if !(__Dbg_flg )
147     .section        .MR_KERNEL,"ax"
148     .align  4
149     .global __Dbg_idle
150     .global __Dbg_RUNtsk,__Dbg_int_entry,__Dbg_int_exit
151     .global __Dbg_ent_handler,__Dbg_ext_handler,__Dbg_int_exit2
152     .global __Dbg_sys_exit,__Dbg_sys_exit2,__Dbg_sys_timer
153 __Dbg_idle:
154 __Dbg_RUNtsk:
155 __Dbg_int_entry:
156 __Dbg_int_exit:
157 __Dbg_int_exit2:
158 __Dbg_ent_handler:
159 __Dbg_ext_handler:
160 __Dbg_sys_exit:
161 __Dbg_sys_exit2:
162 __Dbg_sys_timer:
163     .endif
164
165     .if     __Dbg_flg
166     .section        MR_Dbg_RAM,"aw"
167     .align  4
168     .global __Dbg_mode
169     .global __Dbg_buffer_start
170     .global __Dbg_buffer_end
171     .global __Dbg_cnt
172     .global __Dbg_addr
173 __Dbg_buffer_start:
174     .space  __Dbg_buffer_size
175 __Dbg_buffer_end:
176 __Dbg_addr:  .space  1*4
177 __Dbg_cnt:   .space  1*4
178 __Dbg_sys_iss:      .space  7*4
179 __Dbg_mode:  .space  1
180     .else
181     .section        .MR_Dbg_RAM,"aw"
182     .align  4
183     .global __Dbg_mode
184     .global __Dbg_buffer_start
185     .global __Dbg_buffer_end
186     .global __Dbg_cnt
187     .global __Dbg_addr
188     .global __Dbg_sys_iss
189 __Dbg_buffer_start:
190 __Dbg_buffer_end:
191 __Dbg_addr:
```

```
192 __Dbg_cnt:
193 __Dbg_mode:
194 __Dbg_sys_iss:
195     .endif
196 ;***************  EIT Vector AREA ***********************
197 ; EIT vector area is set up.
198
199     .section        .EIT_Vector,"awx"
200     .align          4
201     rte                             ;TRAP0
202     nop
203     rte                             ;TRAP1
204     nop
205     rte                             ;TRAP2
206     nop
207     rte                             ;TRAP3
208     nop
209     rte                             ;TRAP4
210     nop
211     rte                             ;TRAP5
212     nop
213     rte                             ;TRAP6
214     nop
215     .if !(__Dbg_flg )
216     bra     __SYSCALL0              ;TRAP7
217     bra     __SYSCALL1              ;TRAP8
218     .else
219     .global  __Dbg_entry0,__Dbg_entry1
220     bra     __Dbg_entry0
221     bra     __Dbg_entry1
222     .endif
223     rte                             ;TRAP9
224     nop
225     rte                             ;TRAP10
226     nop
227     rte                             ;TRAP11
228     nop
229     rte                             ;TRAP12
230     nop
231     rte                             ;TRAP13
232     nop
233 ;   rte                             ;TRAP14
234 ;   nop
235 ;   rte                             ;TRAP15
236 ;   nop
237     .section        .Int_Vector,"awx"
238     .balign         4
239     .global __int_entry
240     bra     __int_entry
241
242
243 .if  __MR_EXC_HANDLER
244     .global __DEF_EXC_HDR
245 __DEF_EXC_HDR:
246     vret_exc
247 .endif
248
249 ;   .section        .RESET_VECT,"ax"
250 ;   .align          4
251 ;reset:
252 ;   bra     __START
```

Figure 8.4 Startup Program for C Language(for DCC/M32R)

8.3 Customizing the Section File

8.3.1 Using CC32R

This subsection describes the way of laying out memory for application program data. To lay out memory, you use the section file (section) that comes with the MR32R.
This file is delivered to the linker as the linker's section-allocating option. Allocate sections and set the start addresses in conformity with your system.[70]
Usually, write section namessubsequent to -SEC. To transfer the data to the built-in DRAM from an external ROM, precede the target section names with an @. An example is given below. Arrow in the figure stand for transfer in the arrow direction (from ROM to RAM).

-SEC
RESET_VECTOR,EIT_Vector=40,Int_Vector=80,MR_KERNEL=100,MR_KERNEL2,START_UP,OS_DEBUG,P,D,C,MR_ROM,INTERRUPT_VECTOR,MR_RAM=0F00000,@MR_ROM,@INTERRUPT_VECTOR,MR_Dbg_RAM,SYS_STACK,INT_USR_STACK,MR_HEAP,B,D,EXT_MR_RAM=1000000,EXT_USR_STACK,EXT_MR_HEAP

[70] CC32R User's Manual discribes details.

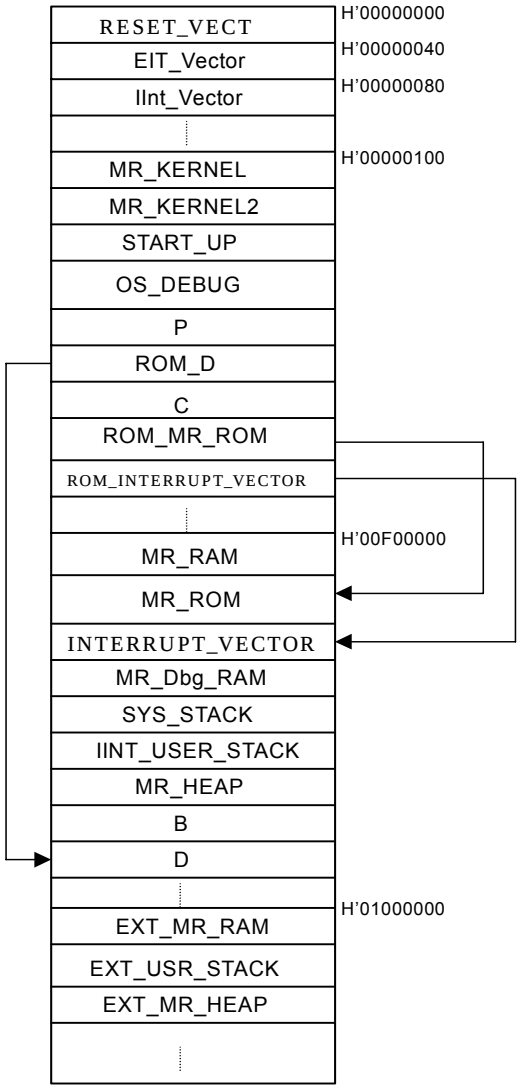


Figure 8.5 The memory image of a sample section file

8.3.2 Using TW32R

To lay out memory, you use the linker script (m32r.cmd) that comes with the MR32R. This file is used when executing the linker (m32r-elf-ld). Symbols defined in the MR32R and the contents of the sample files attached to the product are explained here. As for the details of how to describe linker scripts, see "User's Guide" attached to the TW32R or the on-line documents as to the linker (m32r-elf-ld).

Symbols defined in the linker scripts

- EIT_OF_RAM
  Stands for the start address of the area to be used by TRAP. Subject to invariance.

- Int_OF_RAM
  Stands for the start address of the interrupt vector area.

- START_OF_RAM
  Stands for the start address of the RAM area assigned no initial values.

- START_OF_MR_RAM
  Stand for the start address of the built-in RAM data area of MR32R.

- START_OF_EXT_OF_RAM
  Stands for the start address of the external RAM data domain of MR32R.

- RESET
  Stands for the start address of the reset vector.

8.3.3 Sample Linker Script

```
 1 /*
 2  * m32r.cmd -- Linker script for M32R & MTM
 3  * This script is based on `m32r-elf/lib/ldscripts/m32relf.x'.
 4  * @(#) m32r.cmd 1.2@(#) 99/03/16
 5  * $Id: m32r.cmd,v 1.2 2001/04/18 06:24:31 inui Exp $
 6  */
 7
 8 /*[System Calls(You selected)]*/
 9 /*
10  * Users are not allowed to remove and modify the below
11  * blocks because MTM should handle these blocks:
12  *   - MTM_INPUT
13  *   - MTM_SEARCH_DIR
14  *   - MTM_GROUP
15  */
16 /* Since TM uses this portion, please do not correct.*/
17
18 /*[MTM_INPUT_TOP]*/
19 /*[MTM_INPUT_END]*/
20 /*[MTM_SEARCH_DIR_TOP]*/
21
22 /*[MTM_SEARCH_DIR_END]*/
23 /*[MTM_GROUP_TOP]*/
24 /*[MTM_GROUP_END]*/
25
26
27 OUTPUT_FORMAT("elf32-m32r", "elf32-m32r", "elf32-m32r")
28 OUTPUT_ARCH(m32r)
29 ENTRY(__START)
30 /* Do we need any of these for elf?
31    __DYNAMIC = 0;    */
32
33 /* Memory Layout
34  *   This layout is just example.  Applying this example, it
35  *   is able to check a linking process exactly.
36  *
37  */
38 MEMORY
39 {
40     in_rom   : org = 0, len = 4M
41     in_ram1  : org = 0xf00000, len = 64K
42     out_ram1 : org = 0x1000000, len = 4M
43 }
44
45 /* Section Layout
46  *
47  *   <section name>  <placed in>     <placed in while executing>
48  *   .reset          ROM             ROM
49  *   .EIT_Vector     ROM             ROM
50  *   .Int_Vector     ROM             ROM
51  *   .text           ROM             ROM
52  *   .rodata         ROM             ROM
53  *   .data           ROM             RAM
54  *   .sdata          ROM             RAM
55  *   .sbss           RAM             RAM
56  *   .bss            RAM             RAM
57  *   .heap           RAM             RAM
58  *   .spu_stack              RAM             RAM
59  *   .spi_stack              RAM             RAM
60  */
61
62 SECTIONS
```

```
 63 {
 64 /* The symbol which determines memory allocation is defined. */
 65
 66   RESET = 0;
 67   EIT_OF_ROM = 0x40;
 68   INT_OF_ROM = 0x80;
 69   START_OF_ROM = 0x100;
 70   START_OF_RAM = 0xf00000;
 71   START_OF_EXT_RAM = 0x1000000;
 72
 73 /* Location counter is set to RESET.*/
 74
 75   . = RESET;
 76   /* reset vector sections */
 77   .reset (RESET) :
 78   }
 79      *(.RESET_VECT)
 80   }
 81
 82 /*  The start address of .EIT_Vector is defined as EIT_OF_ROM */
 83
 84   .EIT_Vector (EIT_OF_ROM) :
 85   {
 86     __eit_start = .;
 87     *(.EIT_Vector)
 88     __eit_end = .;
 89   } = 0
 90
 91   PROVIDE (EIT_Vector = .);
 92
 93 /* The start address of .Int_Vector is defined as INT_OF_ROM */
 94
 95   .Int_Vector (INT_OF_ROM) :
 96   {
 97     __Int_start = .;
 98     *(.Int_Vector)
 99     __Int_end = .;
100   } = 0
101
102 /* The start address of .MR_KERNEL is defined as START_OF_ROM */
103
104   .MR_KERNEL (START_OF_ROM) :
105   {
106      __mr_kernel_start = .;
107     *(.MR_KERNEL)
108     *(.MR_KERNEL2)
109     *(.OS_DEBUG)
110      __mr_kernel_end = .;
111   } =0
112
113 /* The start address of .STARTUP is defined */
114
115   .STARTUP (.) :
116   {
117     *(.STARTUP)
118   }
119
120 /* The start address of .text is defined */
121
122   .text (.) :
123   {
124     __text_start = .;
125     *(.text)
126     /* .gnu.warning sections are handled specially by elf32.em.  */
```

```
127    *(.gnu.warning)
128    *(.gnu.linkonce.t*)
129    __text_end = .;
130  } =0
131  _etext = .;
132  PROVIDE (etext = .);
133
134 /* The start address of .rodata is defined */
135
136  .rodata (.) :
137  {
138    __rodata_start = .;
139    *(.rodata)
140    *(.gnu.linkonce.r*)
141    __rodata_end = .;
142  } =0
143
144 /* The start address of .MR_RAM is defined as START_OF_MR_RAM */
145
146  .MR_RAM (START_OF_MR_RAM) :
147 {
148     *(.MR_RAM)
149     *(.MR_Dbg_RAM)
150  }
151
152  /* Adjust the address for the data segment.  We want to adjust up to
153     the same address within the page on the next page up.  */
154
155 /* The start address of .data is defined */
156
157  .data (ADDR(.MR_RAM)+SIZEOF(.MR_RAM)) : AT( LOADADDR(.rodata) + SIZEOF(.roda
    ta) )
158  {
159    __data_start = .;
160    *(.data)
161    *(.gnu.linkonce.d*)
162    CONSTRUCTORS
163    __data_end = .;
164  }
165  __rom_data = LOADADDR(.data);
166
167  /* We want the small data sections together, so single-instruction offsets
168     can access them all, and initialized data all before uninitialized, so
169     we can shorten the on-disk segment size.  */
170
171 /* The start address of .sdata is defined */
172
173  .sdata (ADDR(.data)+SIZEOF(.data)) : AT( LOADADDR(.data) + SIZEOF(.data) )
174  {
175    __sdata_start = .;
176    *(.sdata)
177    __sdata_end = .;
178  }
179  __rom_sdata = LOADADDR(.sdata);
180
181 /* The start address of .MR_ROM is defined */
182
183  .MR_ROM (ADDR(.sdata)+SIZEOF(.sdata)) : AT( LOADADDR(.sdata) + SIZEOF(.sdata
    ) )
184  {
185    __mr_rom_start = .;
186    *(.MR_ROM)
187    *(.INTERRUPT_VECTOR)
188    __mr_rom_end = .;
189  }
```

```
190   __rom_mr_rom = LOADADDR(.MR_ROM);
191
192   _edata  =  .;
193   PROVIDE (edata = .);
194
195 /* The start address of .SYS_STACK is defined */
196
197   .SYS_STACK (.) :
198   {          /* Interrupt stack sections */
199      __spi_start = .;
200      *(.SYS_STACK)
201      __spi_end = .;
202   }
203
204 /* The start address of .INT_USR_STACK is defined */
205
206   .INT_USR_STACK (.)  :
207   {          /* User stack sections */
208      __int_spu_start = .;
209      *(.INT_USR_STACK)
210      __int_spu_end = .;
211   }
212
213 /* The start address of .MR_HEAP is defined */
214
215   .MR_HEAP (.)  :
216   {                  /* Heap space sections */
217      __int_mpl_start = .;
218      *(.MR_HEAP)
219      __int_mpl_end = .;
220   }
221
222   .sbss (.) :
223     {
224      __sbss_start = .;
225      *(.sbss)
226      *(.scommon)
227      __sbss_end = .;
228     }
229   .bss (.) :
230     {
231      __bss_start = .;
232      *(.dynbss)
233      *(.bss)
234      *(COMMON)
235      __bss_end = .;
236     }
237   _end = . ;
238   PROVIDE (end = .);
239
240 /* The start address of .EXT_MR_RAM is defined */
241
242   .EXT_MR_RAM (START_OF_EXT_RAM) :
243   {
244      *(.EXT_MR_RAM)
245   }
246
247 /* The start address of EXT_USR_STACK is defined */
248
249   .EXT_USR_STACK (.)  :
250   {          /* User stack sections */
251      __ext_spu_start = .;
252      *(.EXT_USR_STACK)
253      __ext_spu_end = .;
```

```
254  }
255
256 /* The start address of .EXT_MR_HEAP is defined */
257
258  .EXT_MR_HEAP (.) :
259  {                  /* Heap space sections */
260     __ext_mpl_start = .;
261     *(.EXT_MR_HEAP)
262     __ext_mpl_end = .;
263  }
264
265 /* Debugging information is arranged. This portion is not deleted. */
266
267  /* Stabs debugging sections.  */
268  .stab 0 : { *(.stab) }
269  .stabstr 0 : { *(.stabstr) }
270  .stab.excl 0 : { *(.stab.excl) }
271  .stab.exclstr 0 : { *(.stab.exclstr) }
272  .stab.index 0 : { *(.stab.index) }
273  .stab.indexstr 0 : { *(.stab.indexstr) }
274  .comment 0 : { *(.comment) }
275  /* DWARF debug sections.
276     Symbols in the DWARF debugging sections are relative to the beginning
277     of the section so we begin them at 0.  */
278  /* DWARF 1 */
279  .debug         0 : { *(.debug) }
280  .line          0 : { *(.line) }
281  /* GNU DWARF 1 extensions */
282  .debug_srcinfo  0 : { *(.debug_srcinfo) }
283  .debug_sfnames  0 : { *(.debug_sfnames) }
284  /* DWARF 1.1 and DWARF 2 */
285  .debug_aranges  0 : { *(.debug_aranges) }
286  .debug_pubnames 0 : { *(.debug_pubnames) }
287  /* DWARF 2 */
288  .debug_info    0 : { *(.debug_info) }
289  .debug_abbrev   0 : { *(.debug_abbrev) }
290  .debug_line    0 : { *(.debug_line) }
291  .debug_frame    0 : { *(.debug_frame) }
292  .debug_str     0 : { *(.debug_str) }
293  .debug_loc     0 : { *(.debug_loc) }
294  .debug_macinfo  0 : { *(.debug_macinfo) }
295  /* SGI/MIPS DWARF 2 extensions */
296  .debug_weaknames 0 : { *(.debug_weaknames) }
297  .debug_funcnames 0 : { *(.debug_funcnames) }
298  .debug_typenames 0 : { *(.debug_typenames) }
299  .debug_varnames  0 : { *(.debug_varnames) }
300 }
```

8.3.4 Using DCC/M32R

To lay out memory, you use the linker script (m32r.cmd) that comes with the MR32R. This file is used when executing the linker (dld). Symbols defined in the MR32R and the contents of the sample files attached to the product are explained here. As for the details of how to describe linker scripts, see the documents attached to the DCC/M32R.

8.3.5 Sample Linker Script

```
/*
 * m32r.cmd -- Linker script for M32R
 * @(#) m32r.cmd 1.0@(#) 2000/05/18
 * $Id: m32r.cmd,v 1.2 2001/04/18 06:24:30 inui Exp $
 */

/* Memory Layout
 *   This layout is just example.  Applying this example, it
 *   is able to check a linking process exactly.
 *
 */
/*
Define the size and start address of each area, such as in_rom1 and in_rom2.
*/

MEMORY
{
     in_rom1  : org = 0x0,           len = 0x10
     in_rom2  : org = 0x40,          len = 0x40
     in_rom3  : org = 0x80,          len = 0x10
     in_rom4  : org = 0x100,         len = 0x3fff00
     in_ram1  : org = 0xf00000       len = 0x10000
     out_ram1 : org = 0x1000000,     len = 0x400000
}

/* Section Layout
 *
 *   <section name>  <placed in>     <placed in while executing>
 *   .reset          ROM             ROM
 *   .EIT_Vector     ROM             ROM
 *   .Int_Vector     ROM             ROM
 *   .text           ROM             ROM
 *   .data           ROM             RAM
 *   .bss            RAM             RAM
 *   .heap           RAM             RAM
 *   .spu_stack              RAM             RAM
 *   .spi_stack              RAM             RAM
 */

/* Section arrangement is performed.*/

SECTIONS
{
  GROUP : {
    .RESET_VECT : { *(.EIT_Vector) }
  } > in_rom1

  GROUP : {
    .EIT_Vector : { *(.EIT_Vector) }
  } > in_rom2

  GROUP : {
    .Int_Vector : {  *(.Int_Vector) }
  } > in_rom3

  GROUP : {
    .MR_KERNEL : {
      *(.MR_KERNEL)
      *(.MR_KERNEL2)
      *(.OS_DEBUG)
    }
    .text : {
      *(.text)
```

```
64      *(.text2)
65      *(.init)
66      *(.fini)
67      *(.rodata)
68    }
69    .STARTUP : {*(.STARTUP)}
70  } > in_rom4
71
72  GROUP :{
73
74    .MR_RAM : {*(.MR_RAM) *(.MR_Dbg_RAM)}
75
76 /* Arrange .data section. The start address of the section is defined as
77 __START_data and the end address of the section is defined as __END_data.
78 The transmitting agency address is taken as __ROM_data. The last of a file
79 defines transmitting agency address__ROM_data. */
80
81    __START_data = .;
82    .data LOAD(__ROM_data): {
83      *(.data)
84    }
85    __END_data = .;
86
87 /* Arrange .MR_ROM section. The start address of the section is defined as
88 __START_MR_ROM and the end address of the section is defined as __END_MR_ROM.
89 The transmitting agency address is taken as __ROM_MR_ROM. The last of a file
90 defines transmitting agency address__ROM_data. */
91
92    __START_MR_ROM = .;
93    .MR_ROM LOAD(__ROM_MR_ROM): {
94      *(.MR_ROM)
95      *(.INTERRUPT_VECTOR)
96    }
97    __END_MR_ROM = .;
98
99    .bss : {
100     __START_bss = .;
101     *(.sbss)
102     *(.bss)
103     *[COMMON]
104     __END_bss = .;
105   }
106   __SP_INIT = .;
107   .SYS_STACK : {*(.SYS_STACK)}
108   __SP_END = .;
109   .INT_USR_STACK : {*(.INT_USR_STACK)}
110   .MR_HEAP : {*(.MR_HEAP)}
111     __HEAP_START=.;
112 } > in_ram1
113
114 GROUP :{
115   .EXT_MR_RAM :{*(.EXT_MR_RAM)}
116   .EXT_USR_STACK :{*(.EXT_USR_STACK)}
117   .EXT_MR_HEAP :{*(.EXT_MR_HEAP)}
118 } > in_ram2
119
120 }
121
122 /* Some required symbols are defined. */
123
124 __ROM_data = addr(.START_UP) + sizeof(.START_UP);
125 __ROM_MR_ROM = __ROM_data + sizeof(.data);
126 __BSS_START = __START_bss;
127 __BSS_END = __END_bss;
```

```
128 __DATA_ROM = __ROM_data;
129 __DATA_RAM = __START_data;
130 __DATA_END = __END_data;
131
132 __HEAP_END = addr(in_ram2) + sizeof(in_ram2);
133
```

Figure 8.6 The memory image of a sample linker script file

8.4 Editing makefile

8.4.1 Using CC32R

Here you edit makefile the configurator generated, and set compilation options, libraries, and so on. The procedure for setting them is given below.

1. **cc32R command options**

   You define command options of the C compiler in "CFLAGS". Be sure to define the "-c" option.

2. **as32R command options**

   You define command options of the assembler in "ASFLAGS".

3. **lnk32R command options**

   You define command options of the linker in "LDFLAGS". There are no particular options you need to specify.

4. **Specifying libraries**

   To appoint a library, first, put 'echo"-L library path">>lnk32R.sub' in the library path line.
   Next, put 'echo"-l library name" >> lnk32R.sub' in the library appointing line
   An example is given below that appoints smp.lib held in the director smp32r

```
lnk32r.sub:makefile
        echo –o $(PROGRAM) > lnk32R.sub
        echo –L $(LIB32R) >> lnk32R.sub
        echo –l c32Rmr.lib >> lnk32R.sub
        echo –l mr32R.lib >> lnk32R.sub
  # Here follow steps to appoint a library.
  # Appoint a library path.
        echo –L c:¥mtool¥mr32r¥smp32r >> lnk32R.sub
        echo –l smp.lib >> lnk32R.sub
```

8.4.2 Using D-CC/M32R

Here you edit makefile the configurator generated, and set compilation options, libraries, and so on. The procedure for setting them is given below.

1. **DCC command options**

   You define command options of the C compiler in "CFLAGS". Be sure to define the "-c" option.

2. **DAS command options**

   You define command options of the assembler in "ASFLAGS".

3. **DLD command options**

   You define command options of the linker in "LDFLAGS".

4. **Specifying libraries**

   To appoint a library, first, put 'echo"-L library path">>tmp.cmd' in the library path line.
   Next, put 'echo"-l library name" >> tmp.cmd' in the library appointing line
   An example is given below that appoints smp.lib held in the director smp32r

```
$(PROGRAM).x: $(ALLOBJS) makefile m32r.cmd
      @echo¥$(LDFLAGS) > tmp.cmd
#   Specify library
#   Specify library path.
      @echo –L c:¥mtool¥mr32r¥smp32r >> tmp.cmd
      @echo –l smp.lib >> tmp.cmd
      @echo¥$(LDFLAGS) > tmp.cmd
      @echo¥$(OBJS1)  >> tmp.cmd
      @echo¥$(OBJS2)  >> tmp.cmd
```

Chapter 9 Application Creation Guide

9.1 Processing Procedures for System Calls from Handlers

When a system call is issued from a handler, task switching does not occur unlike in the case of a system call from a task. However, task switching occurs when a return from a handler is made.
The processing procedures for system calls from handlers are roughly classified into the following three types.

1. **A system call from a handler that caused an interrupt during task execution**
2. **A system call from a handler that caused an interrupt during system call processing**
3. **A system call from a handler that caused an interrupt (multiplex interrupt) during handler execution**

9.1.1 System Calls from a Handler That Caused an Interrupt during Task Execution

Scheduling (task switching) is initiated by the ret_int system call (See Figure 9.1)

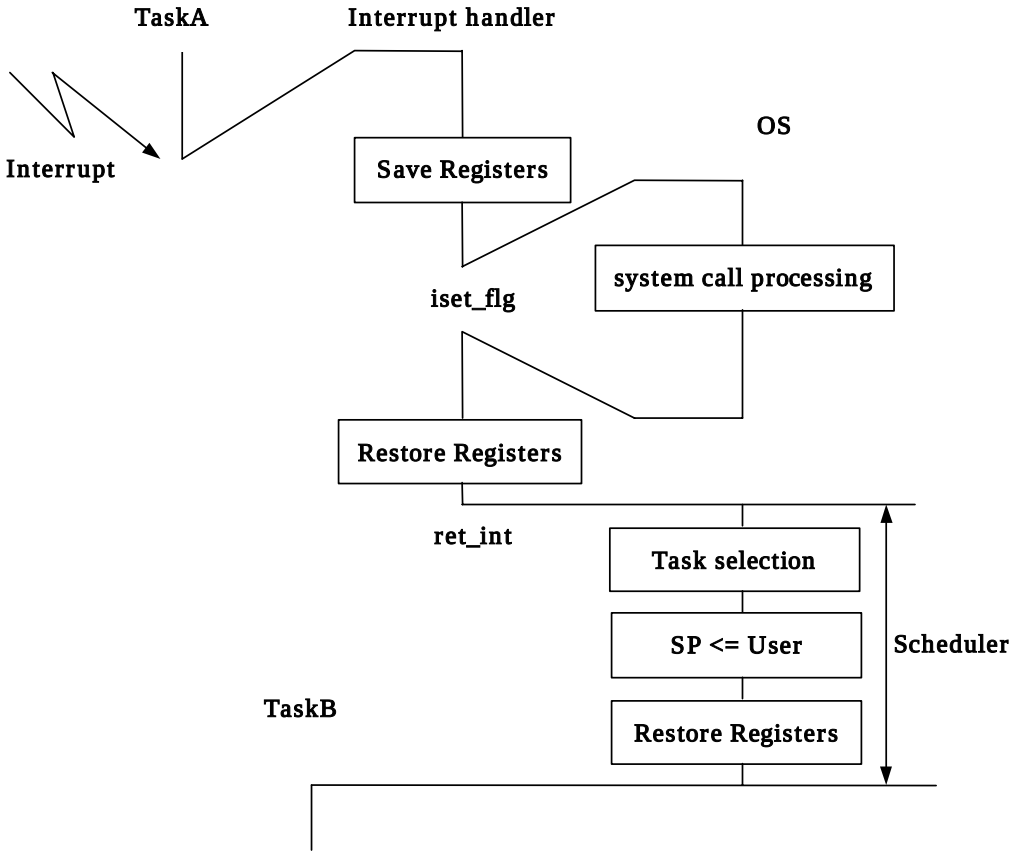


Figure 9.1 Processing Procedure for a System Call a Handler that caused an interrupt during Task Execution

9.1.2 System Calls from a Handler That Caused an Interrupt during System Call Processing

Scheduling (task switching) is initiated after the system returns to the interrupted system call processing (See Figure 9.2).

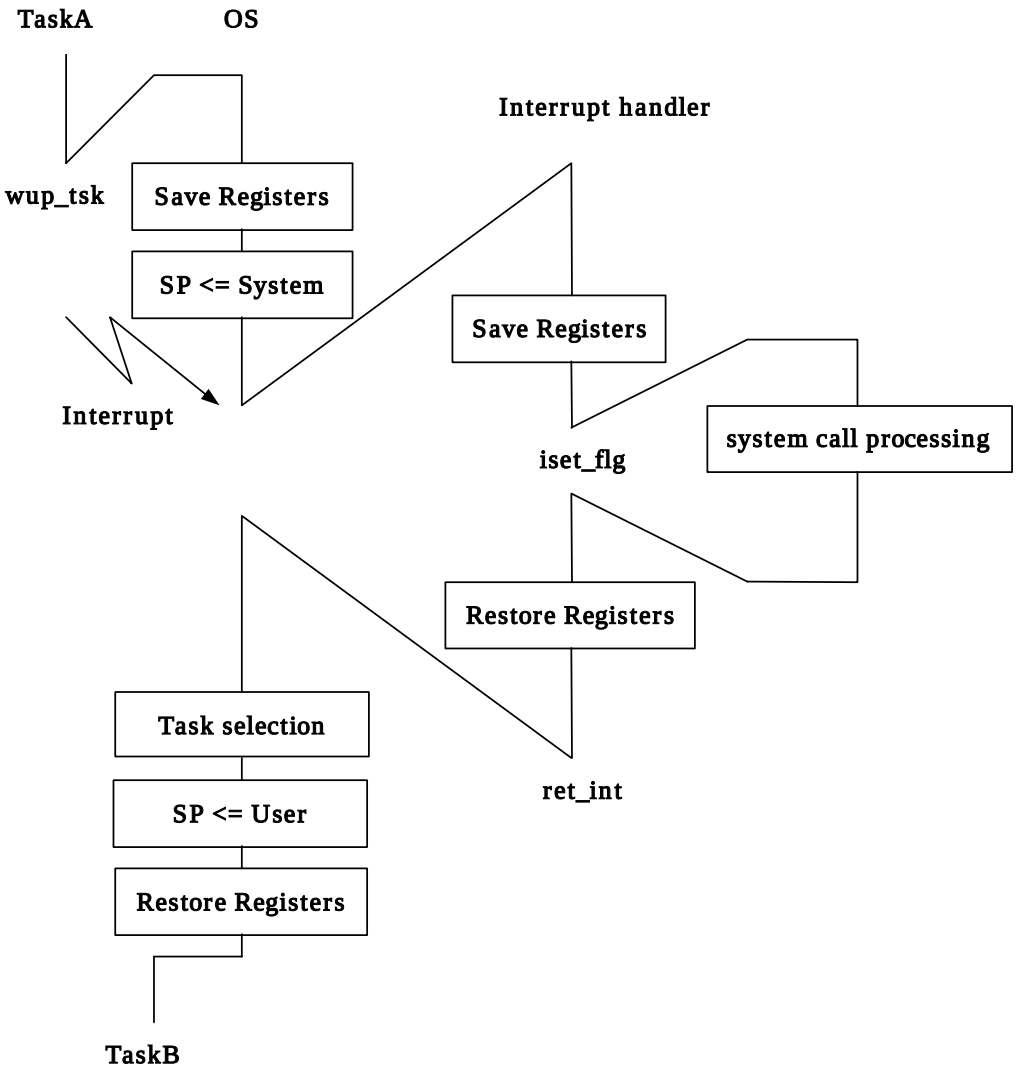


Figure 9.2 Processing Procedure for a System Call from a Handler that caused an interrupt during System Call Processing

9.1.3 System Calls from a Handler That Caused an Interrupt during Handler Execution

Let us think of a situation in which an interrupt occurs during handler execution (this handler is hereinafter referred to as handler A for explanation purposes). When task switching is called for as a handler (hereinafter referred to as handler B) that caused an interrupt during handler A execution issued a system call, task switching does not take place during the execution of the system call (ret_int system call) returned from handler B, but is effected by the ret_int system call from handler A (See Figure 9.3).

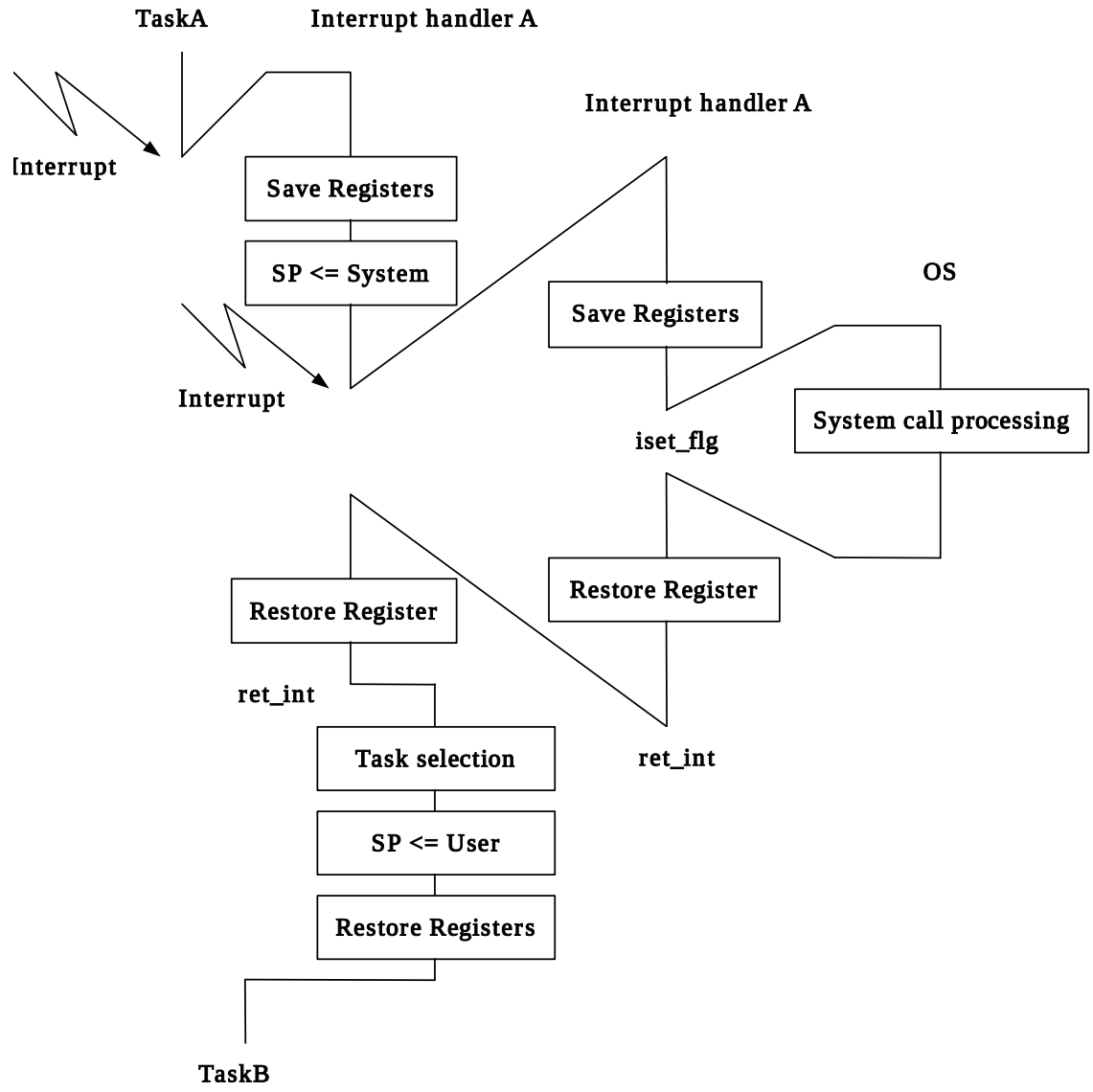


Figure 9.3 Processing Procedure for a system call from a Multiplex interrupt Handler

9.2 Calculating the Amount of RAM Used by the System

The RAM used by the MR32R kernel to manage tasks, etc. is placed in the MR_RAM section. If the dynamic OS object creation function is used, the sum of the MR_ROM section size and the MR_RAM section size. Because MR_ROM section must be transferred to RAM in uing the dynamic OS object creation functio. Table 9.1, Table 9.2 and Table 9.3 show the amount of RAM used by the system. (Note: The stack size used by the system and the task are not included.)
Note: The interrupt vector tables were allocated in MR_ROM as before, but it is allocated in INTERRUPT_VECTOR section now. This section must be transferred from ROM are to RAM area if def_int system call is used.
See the Refference Manual for the stack size calculation method.

Table 9.1 The Size of MR_RAM Section

Area Name	Bytes(4 bytes alignment regulation is needed for each section)
System Management Area	24 + 4 × (priority + maximum task[71] × 2 + maximum flag[71] + maximum semaphore[71] + maximum mailbox[71] + maximum variable-size memorypool[71] + maximum fixed-size memory-pool[71] + maximum messagebuffer[71] × 2 + maximum rendez-vous port[71] × 2 + 2 + maximum priority × the number of mailbox specified as TA_TPRI + priority × the number of mailbox speci-fied as TA_TFIFO + maximum priority × (the number of maxi-mum mailbox with priority – the number of mailbox with priority defined in the configuration file)
Task Management Area	37 × maximum task[71](Forced exception function is unused))
	43 × maximum task [71](Forced exception function is used)
Eventflag Management Area	11 × maximum eventflag[71] + (maximum eventflag – 1) / 8 + 4
Semaphore Management Area	8 × maximum semaphore[71] + (maximum semaphore[71] – 1) / 8 + 4
Mailbox Management Area	17 × maximum mailbox[71] + (maximum mailox[71] – 1) / 8 + 4
Mailbox Area	total mailbox buffer size
Message buffer Management Area	21 × maximum message buffer[71] + (maximum message buffer[71] – 1) / 8 + 4
Message buffer Area	total message buffer size
Rendezvous port Management Area	6 × maximum rendezvous port[71] + (maximum rendezvous port[71] – 1) / 8 + 4
Mailbox with priority Management Area	8 × the number of maximum mailbox with priority[71] + (the num-ber of maximum mailbox with priority[71] –1)/8+4
Fixed-size Memorypool Management Area	9 × maximum fixed-size memorypoo[71] + (maximum fixed-size memorypool[71] – 1) / 8 + 4
Variable-size Memorypool Manage-ment Area	81 × maximum variable-size memorypool[71] + (maximum vari-able-size memorypool[71] – 1) / 8 + 4
Cyclic handler Management Area	5 × maximum cyclic handler
Alarm handler Management Area	1
Task Management Area (dynamic creation)[72]	68(Internal RAM) 68(External RAM)
Mailbox Management Area (dynamic creation)[72]	72(Internal RAM)) 72(External RAM)
Message buffer Management Area (dynamic creation)[72]	72(Internal RAM) 72(External RAM)
Fixed-size memorypool Management	72(Internal RAM)

[71] This is the value defined in the maximum item definition of the configuration file. If this item is not defined, it means the value staticaly defined in the configuration file.
[72] It is secured when dynamic generation of OS objects(cre_tsk,del_tsk,cre_mbx) is used.

Area (dynamic creation)[72]	72(External RAM)
Variable-size memorypool Management Area (dynamic creation)[72]	72(Internal RAM) 72(External RAM)

(Note) System management area is always secured.If you specify the maximum number definition for other items as 0 or you omit the maximum number definition, the area of corresponding items is not secured.
For example, If you specify “max_sem = 0;” and does not define semaphore, the Semaphore management area does not use any memory.

Table 9.2 The Size of MR_ROM Section

Area Name	Bytes(4 bytes alignment regulation is needed for each section)
System time Management Area	6
System Management Area	(Initial start task + 1) × 2
Task Management Area	16 × maximum task[71]
Eventflag Management Area	(maximum eventflas[71] – 1) / 8 + 4
Semaphore Mamagement Area	8 × maximum semaphore[71] + (maximum semaphore[71] – 1) / 8 + 4
Mailbox Management Area	8 × maximum mailbox[71] + (maximum mailbox[71] – 1) / 8 + 4
Message buffer Management Area	8 × maximum message buffer[71] + (maximum message buffer[71] – 1) / 8 + 4
Rendezvous port Management Area	(maximum rendezvous port[71] – 1) / 8 + 4
Mailbox with priority Management Area	6 × the number of maximum mailbox with priority[71] + (the number of maximum mailbox with priority[71] –1)/8+4
Fixed-size Memorypool Management Area	12 × maximum fixed-size memorypool[71] + (maximum fixed-size memorypool[71] – 1) / 8 + 4
Variable-size Memorypool Management Area	17 × maximum variable-size memorypool[71] + (maximum variable-size memorypool[71] – 1) / 8 + 4
Cyclic handler Management Area	9 × cyclic handler
Alarm handler Management Area	12 × alarm handler
Version Management Area	20(in using get_ver system call)
System call Table	384

(Note) System management area and system time management area are always secured.If you specify the maximum number definition for other items as 0 or you omit the maximum number definition, the area of corresponding items is not secured.
For example, If you specify “max_sem = 0;” and does not define semaphore, the Semaphore management area does not use any memory.

Table 9.3 The Size of INTERRUPT_VECTOR Section

Area Name	Bytes
Interrupt Handler Entry Address Table	(maximum interrupt handler[73] + 1) × 4

[73] This is the maximum interrupt factor value defined in the maximum item definition of the configuration file.

9.3 Stacks

9.3.1 System Stack and User Stack

The MR32R provides two types of stacks: system stack and user stack.

- User Stack
  One user stack is provided for each task. Therefore, when writing applications with the MR32R, it is necessary to furnish the stack area for each task.

- System Stack
  This stack is used within the MR32R (during system call processing). When a system call is issued from a task, the MR32R switches the stack from the user stack to the system stack (SeeFigure 9.4).
  The system stack use the interrupt stack(SPI).

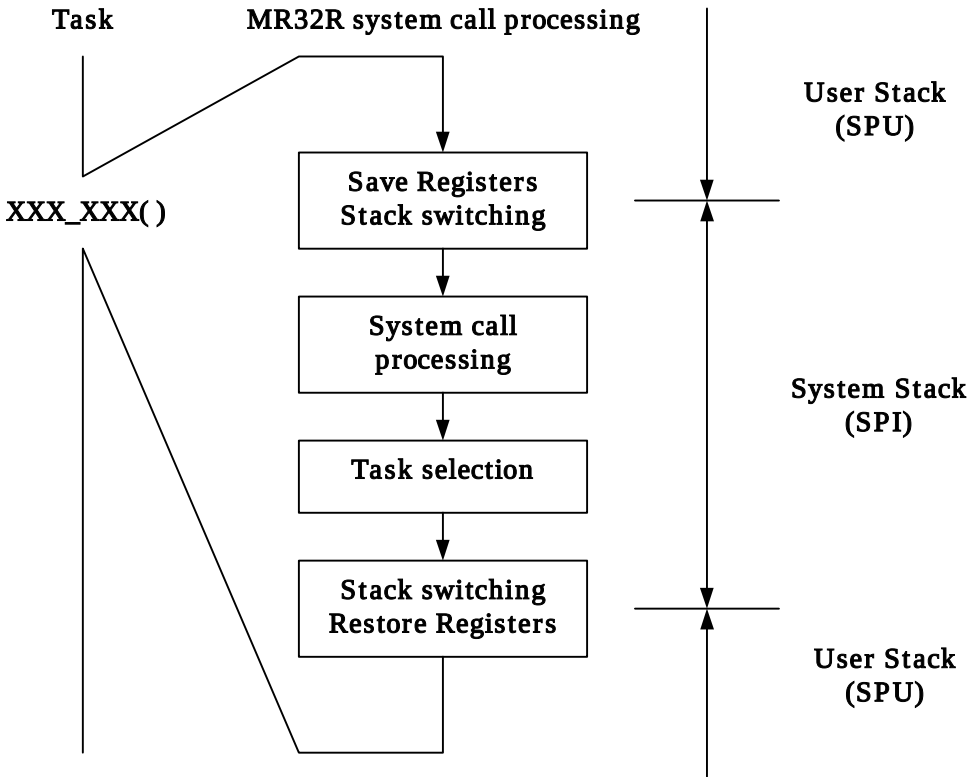


Figure 9.4 System Stack and User Stack

Chapter 10 Apendex

10.1 Sample Program

10.1.1 Overview of Sample Program

Here is a program, as an example of MR32R application, that causes the some messages to perform serial output from the M32102 evaluation board.

Table 10.1 Sample Program Function List

Function Name	Type	ID No.	Priority	Function
main()	Task	1	1	Wakes up task1 and task2
task2()	Task	2	2	Outputs message1.
task3()	Task	3	3	Outputs message2.
alh1()	Handler			Sends message 1 to the mailbox.
chy1()	Handler			Wakes up task2().

Message1: “Hello World!!”
Message2: “MR32R is a Real Time OS for M32R”

Here follows explanation as to how the process works.

- The task main initializes the serial port, starts up task1 and task2, and terminates itself.
- Task1 works in the following sequence.

1. Receives message1 from the mailbox mbx1, and receives the size of message1 from the mailbox mbx2.
2. Outputs received messages to serial port.
3. Gets into the wait state to wait for the system clock to count 100, returns to the execution state to terminate the periodical startup handler, then gets into the wait state to wait for the system clock to count 100 a second time.
4. Returns to the execution state, outputs message1; then resumes the periodical startup handler and clears the period counter simultaneously.
5. Repeats steps 3 and 4.

- Task2 works in the following sequence.

1. Gets into the wait state, and waits until the periodical startup handler wakes it up.
2. When woken up, attempts to secure as much memory as the size of message2.If successful, copies message2 to the area secured.
3. Outputs message2 copied.
4. Releases the area that held message2 in step with the output of message2.
5. Repeats steps 1 though 4.

- alh1 sends message1 to mbx1, and its size to mbx2.
- cyh1 starts up every time the system clock counts 100 to wake task2 up.

10.1.2 Program Source Listing

```
 1 /************************************************************************
 2 *                      MR32R  smaple program
 3 *
 4 * Copyright 2001 MITSUBISHI ELECTRIC CORPORATION
 5 * AND MITSUBISHI ELECTRIC SEMICONDUCTOR APPLICATION ENGINEERING CORPORATION
 6 * All Rights Reserved.
 7 *
 8 *     $Id: smp.c,v 1.2 2001/04/18 06:24:29 inui Exp $
 9 ************************************************************************/
10
11 #include <mr32r.h>
12 #include "id.h"
13
14 void OutputMessage( char *,INT);
15
16 #define     P5MOD           (volatile UH *)(0x00EF106A)
17 #define     SIO0CR          (volatile UH *)(0x00EFD002)
18 #define     SIO0MOD0        (volatile UH *)(0x00EFD006)
19 #define     SIO0MOD1        (volatile UH *)(0x00EFD00A)
20 #define     SIO0STS         (volatile UH *)(0x00EFD00E)
21 #define     SIO0TRCR        (volatile UH *)(0x00EFD012)
22 #define     SIO0BAUR        (volatile UH *)(0x00EFD016)
23 #define     SIO0RBAUR       (volatile UH *)(0x00EFD01A)
24 #define     SIO0TXB         (volatile UB *)(0x00EFD01F)
25
26 void main(void)
27 {
28     *P5MOD = ((0x00ff & 0) | 0x5500);
29     *SIO0CR = 0x0300;
30     *SIO0MOD0 = 0x0100;
31     *SIO0MOD1 = 0x0800;
32     *SIO0BAUR = 34;
33     *SIO0RBAUR = 12;
34     *SIO0TRCR = 0x0000;
35     *SIO0CR = 0x0303;
36
37     sta_tsk(ID_task1,0);
38     sta_tsk(ID_task2,0);
39
40     ext_tsk();
41 }
42 void task1(void)
43 {
44     INT length;
45     char *message1;
46     INT message2;
47
48     rcv_msg((PT_MSG *)&message1,ID_mbx1);
49     rcv_msg((PT_MSG *)&message2,ID_mbx2);
50     OutputMessage(message1,message2);
51
52     while(1){
53             dly_tsk(100);
54             act_cyc(ID_cyh1,TCY_OFF);
55             dly_tsk(100);
56
57             OutputMessage(message1,message2);
58
59             act_cyc(ID_cyh1,TCY_INI_ON);
60     }
61 }
62
```

```
 63 void task2(void)
 64 {
 65     INT length;
 66     ER ercd;
 67     char *message1,*string,*tmp;
 68     INT message2,i;
 69     INT message4 = sizeof("MR32R is a Real Time OS for M32R¥n");
 70     while(1){
 71             slp_tsk();
 72             ercd = pget_blk( (VP *)&string, ID_memblk1,message4);
 73             if( ercd == E_OK ){
 74                     char *message3 = "MR32R is a Real Time OS for M32R¥n";
 75                     tmp = string;
 76                     for( i=0;i<message4;i++){
 77                             *string = *message3;
 78                             *string++;
 79                             *message3++;
 80                     }
 81                     string = tmp;
 82                     OutputMessage(string,message4);
 83                     string = tmp;
 84                     rel_blk( ID_memblk1, string);
 85             }
 86     }
 87 }
 88
 89 void alh1(void)
 90 {
 91     INT message2;
 92     char *message1;
 93     message1 = "Hellow world !!¥n";
 94     message2 = sizeof("Hellow world !!¥n");
 95     isnd_msg(ID_mbx1,(PT_MSG)message1);
 96     isnd_msg(ID_mbx2,(PT_MSG)message2);
 97 }
 98 void cyh1(void)
 99 {
100     iwup_tsk(ID_task2);
101 }
102
103 void OutputMessage(char *message,INT length)
104 {
105     INT i;
106     for(i=0;i<length;i++){
107             while( !((*SIO0STS)&0x0001));
108             *SIO0TXB = *message++;
109     }
110 }
111
```

10.1.3 Configuration File

```
 1 //************************************************************************
 2 //
 3 //   Copyright 2001 MITSUBISHI ELECTRIC CORPORATION
 4 //   AND MITSUBISHI ELECTRIC SEMICONDUCTOR APPLICATION ENGINEERING CORPORATION
 5 //
 6 //   MR32R System Configuration File.
 7 //   smp.cfg
 8 //      $Id: smp.cfg,v 1.2 2001/04/18 06:24:29 inui Exp $
 9 //************************************************************************
10
11 system{
12      stack_size      = 0x1000;
13      priority        = 4;
14      exc_handler     = NO;
15      debug           = NO;
16      debug_buffer    = 0;
17 };
18 //
19 maxdefine{
20      max_task        = 3;
21      max_int         = 32;
22      max_alh =1;
23 };
24 //
25 clock{
26 //   mpu_clock       = 33.3MHz;
27 //   IPL             = 3;
28 //   unit_time       = 100ms;
29      mode            = OTHER;
30 //   mode            = MFT00;
31 //   file_name       = m32102.tpl;
32      initial_time    = 0:0:0;
33 };
34 //
35 task[]{
36      entry_address   = main();
37      stack_size      = 0x1000;
38      stack_area      = INTERNAL;
39      priority        = 1;
40      initial_start   = ON;
41 };
42 task[]{
43      entry_address   = task1();
44      stack_size      = 0x1000;
45      stack_area      = INTERNAL;
46      priority        = 2;
47 };
48 task[]{
49      entry_address   = task2();
50      stack_area      = INTERNAL;
51      stack_size      = 0x1000;
52      priority        = 3;
53 };
54 //
55 mailbox[]{
56      name            = mbx1;
57      mbx_area        = INTERNAL;
58      buffer_size     = 10;
59 };
60 mailbox[]{
61      name            = mbx2;
62      mbx_area        = INTERNAL;
```

```
 63     buffer_size     = 10;
 64 };
 65 //
 66 variable_memorypool[]{
 67     name            = memblk1;
 68     max_memsize     = 0x100;
 69     heap_size       = 0x300;
 70 };
 71 cyclic_hand[]{
 72     interval_counter = 10;
 73     mode             = TCY_ON;
 74     entry_address    = cyh1();
 75 };
 76 //
 77 alarm_hand[]{
 78     time            = 0:00:5;
 79     entry_address   = alh1();
 80 };
 81
 82 systemcall{
 83     cre_tsk         = NO;
 84     del_tsk         = NO;
 85     sta_tsk         = YES;
 86     ter_tsk         = NO;
 87     chg_pri         = NO;
 88     rot_rdq         = NO;
 89     rel_wai         = NO;
 90     ena_dsp         = NO;
 91     sus_tsk         = NO;
 92     rsm_tsk         = NO;
 93     slp_tsk         = YES;
 94     wup_tsk         = NO;
 95     set_flg         = NO;
 96     wai_flg         = NO;
 97     sig_sem         = NO;
 98     wai_sem         = NO;
 99     snd_msg         = NO;
100     rcv_msg         = YES;
101     pget_blf        = NO;
102     rel_blf         = NO;
103     pget_blk        = YES;
104     rel_blk         = YES;
105     unl_cpu         = NO;
106     dly_tsk         = YES;
107     ista_tsk        = YES;
108     ichg_pri        = NO;
109     irot_rdq        = NO;
110     irel_wai        = NO;
111     get_tid         = NO;
112     isus_tsk        = NO;
113     irsm_tsk        = NO;
114     iwup_tsk        = YES;
115     can_wup         = NO;
116     iset_flg        = NO;
117     clr_flg         = NO;
118     pol_flg         = NO;
119     isig_sem        = NO;
120     preq_sem        = NO;
121     isnd_msg        = YES;
122     prcv_msg        = YES;
123     set_tim         = NO;
124     get_tim         = NO;
125     act_cyc         = YES;
126     get_ver         = NO;
127     ret_int         = YES;
```

```
128     dis_dsp         = NO;
129     loc_cpu         = NO;
130     ext_tsk         = YES;
131     exd_tsk         = NO;
132 };
133 interrupt_vector[16] = __sys_timer;
134 //
135 // End of Configuraton
136 //
137
```

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